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SIMRES Acoustic Data Hydroacoustic Measurements

Marine Mammal Detections from February to December 2020 off Monarch Head and East Point, Saturna Island, BC

JASCO Applied Sciences (Canada) Ltd

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Un sommaire français se trouve avant la table des matières.

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16. Abstract

Transport Canada (TC) commissioned JASCO Applied Sciences (JASCO) to analyze underwater sound recordings obtained from the Saturna Island Marine Research and Education Society (SIMRES) at two locations in Boundary Pass, BC. JASCO's automated marine mammal detectors, which are recognition algorithms, for killer whales, humpback whales, and Pacific white-sided dolphins were applied to the data. From 21 Feb to 31 Dec 2020, almost 3000 killer whale vocalizations were validated at Monarch Head on 36 days and almost 4000 at East Point on 42 days. These results suggest that killer whale occurrence has increased in the area when compared to the 2018-2019 data sets. Lower detection counts were observed for humpback whales at both stations, and they were primarily detected during late fall and early winter, which is consistent with previous data sets. There were no validated detections of Pacific white-sided dolphins during the recording period at either station. Overall, this study contributes important information on the occurrence of several species in the Boundary Pass for ongoing research required to investigate factors driving the distributions of marine mammals, specifically southern resident killer whales (SRKW).

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16. Résumé

Transports Canada (TC) a chargé JASCO Applied Sciences (JASCO) d'analyser les enregistrements sonores sous-marins obtenus auprès de la Saturna Island Marine Research and Education Society (SIMRES) à deux endroits dans le passage Boundary, en Colombie-Britannique. Les détecteurs automatisés de mammifères marins de JASCO, qui sont des algorithmes de reconnaissance pour les épaulards, les rorquals à bosse et les dauphins à flancs blancs du Pacifique, ont été appliqués aux données. Du 21 février au 31 décembre 2020, près de 3 000 vocalisations d'épaulards ont été validées à Monarch Head pendant 36 jours et près de 4 000 à East Point pendant 42 jours. Ces résultats suggèrent que la présence des épaulards a augmenté dans la zone par rapport aux ensembles de données de 2018-2019. Des dénombrements de détection plus faibles ont été observés pour les rorquals à bosse aux deux stations, et celles-ci ont été principalement détectées à la fin de l'automne et au début de l'hiver, ce qui est cohérent avec les ensembles de données précédents. Il n'y a pas eu de détections validées de dauphins à flancs blancs du Pacifique pendant la période d'enregistrement à l'une ou l'autre des stations. Dans l'ensemble, cette étude fournit des renseignements importants sur la présence de plusieurs espèces dans le passage Boundary pour les recherches en cours qui sont nécessaires afin d'étudier les facteurs qui déterminent la répartition des mammifères marins, en particulier les épaulards résidents du Sud.

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EXECUTIVE SUMMARY

Transport Canada (TC) commissioned the analysis of underwater sound recordings obtained from the Saturna Island Marine Research and Education Society (SIMRES) at two locations in Boundary Pass, south of Saturna Island, BC: Monarch Head and East Point. The SIMRES hydrophones are part of the British Columbia (BC) Coast Hydrophone Network, which allows for scientific collaboration to monitor underwater soundscape and marine mammals. The Boundary Pass is an important habitat for several marine species, including the endangered southern resident killer whale (SRKW). Much of the SRKW population have consistent and prolonged seasonal occupancy near heavily used shipping lanes. The acoustic environment is an important element of their habitat; however, they experience substantial levels of shipping noise that has the potential to disturb and mask sounds, such as transmitting and receiving their echolocation clicks and other vocalizations essential for navigating, foraging, and engaging in cultural and social activities (DFO 2011). TC recognizes the need to examine underwater noise conditions and determine when and where marine mammals are present, specifically the endangered SRKW. In 2020, the Interim Sanctuary Zone (ISZ) was expanded at the East Point location to further protect the endangered SRKW critical habitat. TC has commissioned this study to assess marine mammal occurrence based on detections of vocalizations in the Boundary Pass, with a focus on killer whales.

JASCO Applied Sciences analyzed underwater sound recordings from SIMRES' hydrophones at Monarch Head (near but outside the ISZ) and East Point (within the ISZ) for the 2020 recording period. Some data gaps were identified as maintenance on the hydrophone systems or power outages. For this report, JASCO's automated marine mammal detectors, which are recognition algorithms, for killer whales, humpback whales, and Pacific white-sided dolphins were applied to the data. The killer whale detector did not differentiate between different ecotypes or populations of killer whales (i.e., Southern Resident, Northern Resident, and Biggs killer whales). An experienced analyst manually verified all candidate detections and discarded any false detections.

From 21 Feb to 31 Dec 2020, almost 3000 killer whale vocalizations were validated at Monarch Head on 36 days and almost 4000 at East Point on 42 days. Killer whales were present throughout all months with useable data, with increased detection counts in fall at both stations and again in December at Monarch Head. Killer whale detection counts increased during spring at East Point. The reported detections of killer whale calls are not separated by ecotype or population. JASCO's nearby Boundary Pass listening station is approximately 1.5 km from SIMRES's Monarch Head station, which analysts manually verify at the ecotype level that both SRKW and Bigg's killer whales are frequently detected in the area. The results here are likely a combination of these two ecotypes. Lower detection counts were observed for humpback whales: almost 2000 detections were validated at Monarch Head on 10 days, whereas less than 1500 were observed at East Point on 9 days. At both stations, humpback whales were primarily detected during late fall and early winter even though visual sightings are common off East Point in summer. There were no validated detections of Pacific white-sided dolphins during the recording period at either station.

From this study, the results suggest that when comparing the validated detectors for killer whales in 2020 to the previous SIMRES data sets (2018–2019), killer whale occurrence has increased. This could be due to multiple factors such as increased data quality allowing for higher detector performance, increased use of habitat by killer whales, and/or less underwater noise pollution from vessels. Killer whales were most commonly detected at East Point. Additional years of data collection and comparison is warranted along with an extension of the ISZ.

Humpback whale detection counts were compared to the previous years (2018–2019). Humpback whales were most commonly detected at the Monarch Head hydrophone location. The results from the Boundary Pass listening station hydrophone further offshore, but only 1.5 km from Monarch Head, indicate that humpback whale detections were most common during November and December. The prolonged occurrence during these months over multiple years suggests this area is a favourable habitat (i.e., productive feeding grounds). It seems that a few whales are staying around the southern Gulf Islands through the winter as observed on the Boundary Pass listening station. More humpbacks have been overwintering in British Columbia waters as their population has had significant recovery. During summer, the humpback whale detector was mainly triggered by the increase of harbour seal vocalizations. Harbour seal vocalizations have similar sounds with some similar features to humpback whale vocalizations and can easily be misidentified by an automated detector. This supports the need for manual validation of the detectors. In addition, there are some call differences that could be addressed by adding a separate pinniped detector.

Pacific white-sided dolphins were not detected in this data set. They have not been commonly detected on the Boundary Pass listening station or in previous years in SIMRES recordings. However, Pacific white-sided dolphins have been recorded year-round off BC and can therefore be considered permanent residents in this area, although they may not be in close proximity to the recording stations or perhaps do not vocalize frequently while in this area.

Overall, this study contributes important information on the occurrence of several species in the Boundary Pass for ongoing research required to investigate factors driving the distributions of marine mammals, specifically SRKW. There is potential for noise effects of anthropogenic activities (i.e., vessels) on marine mammals in these areas of overlap, primarily in the form of communication masking or habitat displacement. Long-term acoustic monitoring, together with visual observations, will allow for continued tracking of animal presence. The implementation of an ISZ off Saturna Island is expected to benefit marine mammal use of the near-shore areas, including its use by SRKW.

SOMMAIRE

Transports Canada (TC) a commandé l'analyse des enregistrements sonores sous-marins obtenus auprès de la Saturna Island Marine Research and Education Society (SIMRES) à deux endroits dans le passage Boundary, au sud de l'île Saturna, en Colombie-Britannique : Monarch Head et East Point. Les hydrophones de la SIMRES font partie du British Columbia (BC) Coast Hydrophone Network, qui permet une collaboration scientifique pour surveiller l'environnement acoustique sous-marin et les mammifères marins. Le passage Boundary est un habitat important pour plusieurs espèces marines, y compris l'épaulard résident du sud (ERS), en voie de disparition. Une grande partie de la population des ERS côtoie de manière saisonnière, constante et prolongée des voies de navigation très achalandées. L'environnement acoustique est un élément important de l'habitat de l'ERS. Cependant, l'ERS est exposé à des niveaux substantiels de bruit de navigation qui peuvent perturber et masquer les sons, tels que la transmission et la réception de ses clics d'écholocalisation et d'autres vocalisations essentielles pour la navigation, la recherche de nourriture et les activités culturelles et sociales (DFO 2011). TC reconnaît la nécessité d'examiner les conditions de bruit sous-marin et de déterminer quand et où les mammifères marins sont présents, en particulier l'ERS en voie de disparition. En 2020, la zone de refuge provisoire (ZRP) a été élargie à l'emplacement d'East Point pour mieux protéger l'habitat essentiel de l'ERS, en voie de disparition. TC a commandé cette étude pour évaluer la présence de mammifères marins en fonction des détections de vocalisations dans le passage Boundary, en mettant l'accent sur les épaulards.

JASCO Applied Sciences a analysé les enregistrements sonores sous-marins des hydrophones de la SIMRES à Monarch Head (près, mais à l'extérieur de la ZRP) et à East Point (dans la ZRP) pour la période d'enregistrement de 2020. Certaines lacunes dans les données comme l'entretien des systèmes d'hydrophones ou des pannes de courant ont été relevées. Pour ce rapport, les détecteurs automatisés de mammifères marins de JASCO, qui sont des algorithmes de reconnaissance pour les épaulards, les rorquals à bosse et les dauphins à flancs blancs du Pacifique, ont été appliqués aux données. Le détecteur d'épaulards n'a pas fait de distinction entre les différents écotypes ou populations d'épaulards (c.-à-d. les épaulards résidents du sud, résidents du nord et les Biggs). Un analyste expérimenté a vérifié manuellement toutes les détections relevées et a rejeté toutes les fausses détections.

Du 21 février au 31 décembre 2020, près de 3 000 vocalisations d'épaulards ont été validées à Monarch Head pendant 36 jours et près de 4 000 à East Point pendant 42 jours. Les épaulards ont été présents pendant tous les mois pour lesquels des données utilisables ont été recueillies, avec une augmentation du nombre de détections en automne aux deux stations et à nouveau en décembre à Monarch Head. Le nombre de détections d'épaulards a augmenté au printemps à East Point. Les détections signalées de vocalisations d'épaulards ne sont pas séparées par écotype ou par population. La station d'écoute de JASCO – à proximité du passage Boundary et qui se trouve à environ 1,5 km de la station de Monarch Head de la SIMRES – que les analystes vérifient manuellement au niveau de l'écotype indique que les épaulards résidents du sud et les Biggs sont fréquemment détectés dans la région. Les résultats ici sont probablement une combinaison de ces deux écotypes. Des décomptes de détection plus faibles ont été observés pour les rorquals à bosse : près de 2 000 détections ont été validées à Monarch Head pendant

10 jours, tandis que moins de 1 500 ont été observées à East Point pendant 9 jours. Aux deux stations, les rorquals à bosse ont été le mammifère le plus détecté à la fin de l'automne et au début de l'hiver, même s'ils sont fréquemment observés au large de East Point pendant l'été. Il n'y a pas eu de détections validées de dauphins à flancs blancs du Pacifique pendant la période d'enregistrement à l'une ou l'autre des stations.

À partir de cette étude, les résultats suggèrent qu'en comparant les détecteurs validés pour les épaulards en 2020 aux précédents ensembles de données (2018-2019) de la SIMRES, le nombre de détections d'épaulards a augmenté. Cela pourrait être dû à de multiples facteurs tels qu'une qualité accrue des données permettant un meilleur rendement des détecteurs, une utilisation accrue de l'habitat par les épaulards et/ou moins de pollution sonore sous-marine provenant des navires. Les épaulards ont été le plus souvent détectés à East Point. Des années supplémentaires de collecte et de comparaison de données sont justifiées ainsi qu'un élargissement de la ZRP.

Le nombre de détections de rorquals à bosse a été comparé à celui des années précédentes (2018-2019). Les rorquals à bosse ont été le plus souvent détectés par l'hydrophone de Monarch Head. Les résultats de l'hydrophone de la station d'écoute du passage Boundary, plus au large, mais à seulement 1,5 km de Monarch Head, indiquent que les détections de rorquals à bosse étaient plus fréquentes en novembre et en décembre. La fréquence prolongée de ces détections au cours de ces mois sur plusieurs années suggère que cette zone est un habitat favorable (c.-à-d. une aire d'alimentation productive). Il semble que quelques baleines restent autour du sud des îles Gulf pendant l'hiver, comme cela a été observé à la station d'écoute du passage Boundary. Un plus grand nombre de rorquals à bosse hivernent dans les eaux de la Colombie-Britannique, car leur population s'est considérablement rétablie. Durant l'été, le détecteur de rorquals à bosse était principalement déclenché par l'augmentation des vocalisations des phoques communs. Les vocalisations des phoques communs ont des sons similaires aux vocalisations des rorquals à bosse et peuvent facilement être mal identifiées par un détecteur automatisé. Cela soutient qu'il est nécessaire de valider manuellement les détections. De plus, certaines différences de vocalisations pourraient être identifiées en ajoutant un détecteur de pinnipèdes distinct.

Les dauphins à flancs blancs du Pacifique n'ont pas été détectés dans cet ensemble de données. Ils n'ont pas été détectés fréquemment à la station d'écoute du passage Boundary ou au cours des années précédentes dans les enregistrements de la SIMRES. Cependant, des détections de dauphins à flancs blancs du Pacifique ont été enregistrées toute l'année au large de la Colombie-Britannique et ils peuvent donc être considérés comme des résidents permanents dans cette zone, même s'ils ne sont peut-être pas à proximité des stations d'enregistrement ou ne vocalisent peut-être pas fréquemment dans cette zone.

Dans l'ensemble, cette étude apporte des renseignements importants sur la présence de plusieurs espèces dans le passage Boundary pour les recherches en cours qui sont nécessaires afin d'étudier les facteurs qui déterminent la répartition des mammifères marins, en particulier les épaulards. Il existe un potentiel d'effets sonores des activités anthropiques (c.-à-d. les navires) sur les mammifères marins dans ces zones de chevauchement, principalement sous la forme de masquage des communications ou de déplacement de l'habitat. Une surveillance

acoustique à long terme ainsi que des observations visuelles permettront un suivi continu de la présence animale. La mise en place d'une ZRP au large de l'île Saturna devrait favoriser l'utilisation des zones côtières par les mammifères marins, notamment par les ERS.

CONTENTS

FIGURES

TABLES

1. INTRODUCTION

Transport Canada (TC) commissioned JASCO Applied Sciences (JASCO) to analyze underwater sound recordings obtained from the Saturna Island Marine Research and Education Society (SIMRES) at two locations in Boundary Pass, south of Saturna Island, BC: Monarch Head and East Point. These recorders are located within the southern resident killer whale (SRKW) critical habitat and humpback whale habitat. This data set is an extension of the 2018–2019 SIMRES data collection to allow for measurements of the Interim Sanctuary Zone (ISZ) expansion to be compared to the 2018–2019 SIMRES recordings.

Biological sources of sound are diverse, and many marine taxa produce sounds. Animals that live in the habitat near the acoustic recorders and that are known to emit acoustic signals include crustaceans, fish, and several marine mammal species. Marine mammal vocalizations are the best documented biological contributors to the ocean soundscape and were present in the SIMRES 2020 recordings. Bioacousticians are able to determine which species are present from their detected vocalizations. The primary purpose of this analysis is to determine the temporal and spatial understanding of the species in the area, particularly the endangered SRKWs. Humpback whale and fish sounds are also examined.

Thirty-one marine mammal species frequent Pacific Canadian waters, and twelve of these species are considered at risk (Table 1). At-risk species and their habitat are protected by existing national park and marine conservation area regulations and management regimes, as well as by the Species At Risk Act (SARA; Parks Canada 2016). Parks Canada is responsible for the species at risk in the waters it administers. Marine mammals expected to regularly occur in the recording area are killer whales (likely southern residents or Bigg's transients), humpback whales, harbour seals, and Steller's sea lions. Additional species that may be present include Pacific white-sided dolphins, harbour porpoise, Dall's porpoise, and the occasional gray whale. We expect killer whales and humpbacks whales to be present during the 2020 recording, as observed in the previous data sets and real-time research.

Table 1. North Pacific marine mammals and their conservation status under the Species at Risk Act (SARA) and Committee on the Status of Endangered Wildlife in Canada (COSEWIC).

Species name	Scientific name	SARA status	COSEWIC status
Baleen whales (Suborder Mysticeti)			
Blue whale	*Balaenoptera musculus*	Endangered	Endangered
Fin whale	*Balaenoptera physalus*	Threatened	Threatened
Gray whale (North Pacific Migratory population)	*Eschrichtius robustus*	Not listed	Not at risk
Gray whale (Pacific Coast Feeding Group population)		Not listed	Endangered
Gray whale (Western Pacific population)		Not listed	Endangered
Humpback whale	*Megaptera novaeangliae*	Special concern	Special concern
Minke whale	*Balaenoptera acutorostrata scammonii*	Not listed	Not at risk
North Pacific right whale	*Eubalaena japonica*	Endangered	Endangered
Sei whale	*Balaenoptera borealis*	Endangered	Endangered
Toothed whales (Suborder Odontoceti)			
Delphinidae			
Bottlenose dolphin	*Tursiops truncatus*	Not listed	Not at risk
False killer whale	*Pseudorca crassidens*	Not listed	Not at risk
Killer whale (Northern Resident)	*Orcinus orca*	Threatened	Threatened
Killer whale (Offshore)		Threatened	Threatened
Killer whale (Southern Resident)		Endangered	Endangered
Killer whale (Transient)		Threatened	Threatened
Northern right whale dolphin	*Lissodelphis borealis*	Not listed	Not at risk
Pacific white-sided dolphin	*Lagenorhynchus obliquidens*	Not listed	Not at risk
Risso's dolphin	*Grampus griseus*	Not listed	Not at risk
Short-beaked common dolphin	*Delphinus delphis*	Not listed	Not at risk
Short-finned pilot whale	*Globicephala macrorhynchus*	Not listed	Not at risk
Striped dolphin	*Stenella coeruleoalba*	Not listed	Not at risk
Phocoenidae			
Dall's porpoise	*Phocoenoides dalli*	Not listed	Not at risk
Harbor porpoise	*Phocoena phocoena*	Special concern	Special concern

Species name	Scientific name	SARA status	COSEWIC status
Sperm whales (Kogiidae and Physeteridae)			
Dwarf sperm whale	*Kogia sima*	Not listed	Data deficient
Pygmy sperm whale	*Kogia breviceps*	Not listed	Not at risk
Sperm whale	*Physeter macrocephalus*	Not listed	Not at risk
Ziphiidae			
Baird's beaked whale	*Berardius bairdii*	Not listed	Not at risk
Blainville's beaked whale	*Mesoplodon densirostris*	Not listed	Not at risk
Cuvier's beaked whale	*Ziphius cavirostris*	Not listed	Not at risk
Hubbs' beaked whale	*Mesoplodon carlhubbsi*	Not listed	Not at risk
Stejneger's beaked whale	*Mesoplodon stejnegeri*	Not listed	Not at risk
Pinnipeds (Suborder Pinnipedia)			
Harbour seal	*Phoca vitulina richardsi*	Not listed	Not at risk
Northern elephant seal	*Mirounga angustirostris*	Not listed	Not at risk
Steller's sea lion	*Eumetopias jubatus*	Special concern	Special concern
Northern fur seal	*Callorhinus ursinus*	Not listed	Threatened
California sea lion	*Zallophus californicanus*	Not listed	Not at risk
Family Mustelidae			
Sea otter	*Enhydra lutris*	Special concern	Special concern

Three distinct groups, or ecotypes, of killer whales inhabit the waters of BC, each exhibiting different prey preferences, vocal dialects, and social organization. These three types and their conservation status are:

- The Resident population, separated into:
  - The Northeast Pacific Southern Resident population is SARA listed (Endangered);
  - The Northeast Pacific Northern Resident population is SARA listed (Threatened);
- The Northeast Pacific Transient population (or Bigg's killer whale) is SARA listed (Threatened);
- The Offshore population is SARA listed (Threatened).

The acoustic environment is an important element of killer whale habitat; an ocean quiet enough for transmitting and receiving their echolocation clicks and other vocalizations is essential for navigating, foraging, and engaging cultural and social activities. The two distinct populations of resident killer whales, the Northern and Southern residents, occupying the waters of the west coast of BC are acoustically, genetically, and culturally distinct (DFO 2011). Although their ranges overlap, they do not travel together or associate. DFO developed a SARA Action Plan

and a Recovery Strategy these populations (DFO 2017), which was amended in 2018 (DFO 2018). There are two Critical Habitat areas: the SRKW Designated Critical Habitat and northern resident killer whale (NRKW) Designated Critical Habitat. During summer and fall, southern residents are primarily found in the trans-boundary waters of Haro Strait, Boundary Pass, the Strait of Juan de Fuca, and southern portions of the Strait of Georgia. This area is designated as 'critical habitat' based on consistent and prolonged seasonal occupancy.

British Columbia waters are also used by foraging and migrating humpback whales. They are seen year-round in BC waters but are most abundant from April to November. They are the most frequently sighted baleen whale during ship surveys and have recently been regularly sighted in the Salish Sea during summer and early fall (Ford et al. 2014). Humpback whales are generally uncommon in the Strait of Georgia and other inside waters in this region. In general, photo-identification data suggest the existence of two populations in northern and southern BC with different migratory destinations and low rate of exchange (COSEWIC 2011).

Pacific white-sided dolphins have been recorded year-round off BC and can therefore be considered permanent residents in this area, although abundance peaks in summer. The abundance estimate for the inshore waters of BC is 22,160 (95% CI: 16,522–29,721) (Best et al. 2015). This estimate does not include animals in deep oceanic waters west of Vancouver Island. There is evidence that abundance may be increasing in BC, possibly as a result of a climate-induced poleward shift in distribution or a change in the distribution of prey (Heise 1997, Morton 2000, Salvadeo et al. 2010).

In addition to the SIMRES recording stations, underwater acoustic data have been collected continuously in Boundary Pass since December 2018 as part of a long-term measurement program for TC. JASCO's underwater listening station provides real-time data and is in close proximity to the Monarch Head recorder. The same automated detectors for killer whales, humpback whales, and Pacific white-sided dolphins were applied on all acoustic data collected in this area.

This report presents the results of the data collected by SIMRES from February to December 2020 on their East Point and Monarch Head hydrophones. Marine mammal detections were manually validated by an experienced analyst to determine their temporal presence at Monarch Head and East Point. The 2020 results will also be compared to the previous 2018–2018 where possible to comment on any effects of the ISZ expansion.

2. METHODS

Acoustic data were collected by SIMRES using icListen HF hydrophones deployed close to shore off East Point and Monarch Head of Saturna Island (Figure 1). Systems at both locations sampled at 128 kHz and were programmed to record continuously from February to December 2020. Several power outages, maintenance to the systems, and other unforeseen issues are described in Table 3 to address the gaps in the acoustic data. Table 2 lists the hydrophone locations and periods that were used for analysis.

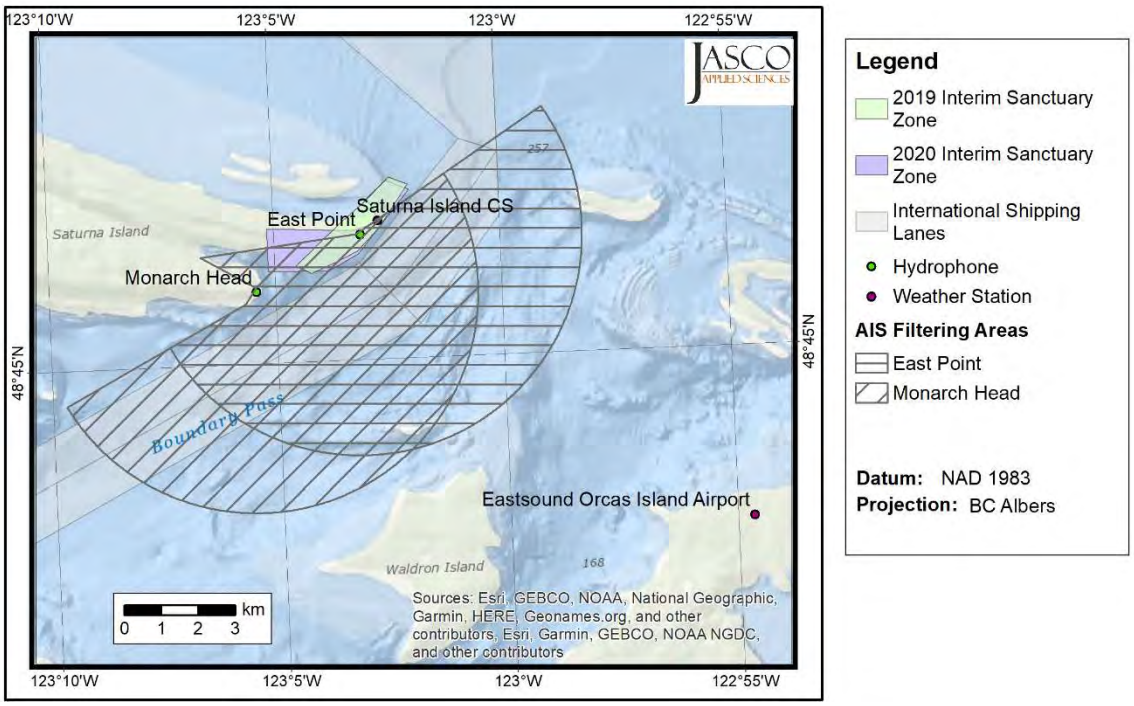

Figure 1. Map of the 2019 and 2020 Saturna Interim Sanctuary Zone (ISZ) and the locations of the hydrophones with their detection range. The map also shows the locations of nearby weather stations and the Automatic Identification System (AIS) filtering areas.

Table 2. Hydrophone locations and periods used for analysis.

Station	icListen	Latitude (N)	Longitude (W)	Water depth (m)	Start date/time (UTC)	End date/time (UTC)
East Point	1283	48°46.8416’	123°03.0808’	20	2020 Feb 21 17:08	2020 Oct 1 18:39
	2096				2020 Oct 3 21:29	2020 Dec 31 23:59
Monarch Head	1289	48°46.0566’	123°05.4228’	20	2020 Feb 21 17:10	2020 Mar 18 10:06
	1376				2020 May 25 21:11	2020 Dec 31 23:59

Table 3. Explanation provided by SIMRES for gaps in acoustic data throughout the recording period at both East Point and Monarch Head.

Station	Start	End	Explanation for gaps in acoustic data
East Point	2020 Jan 1	2020 Feb 21	Reason unknown-both wav and FFT files missing
	2020 Feb 23	2020 Feb 23	Power failure that prevented data from being logged
	2020 Apr 3	2020 Apr 9	Power outages 3–7 Apr, maintenance 9 Apr
	2020 May 1	2020 May 12	IT issue/missing data-both wav and FFT files
	2020 May 17	2020 May 17	Remote maintenance on NUC
	2020 Jun 20	2020 Jun 24	Issues with logging computer, repairs completed 22 Jun
	2020 Jul 7	2020 Jul 22	Old ONC Pepwave router failure, maintenance attempted 16 Jul and equipment replaced 22 Jul
	2020 Aug 20	2020 Aug 21	Reason unknown-both wav and FFT files missing
	2020 Sep 23	2020 Sep 23	System maintenance
	2020 Oct 1	2020 Oct 4	Single hydrophone mooring recovered, 2-element mooring deployed
	2020 Dec 22	2020 Dec 24	Storm knocked out power-new UPS allowed 36 h of additional data collection
Monarch Head	2020 Jan 1	2020 Feb 21	Reason unknown-both wav and FFT files missing
	2020 Feb 23	2020 Feb 23	Power failure at East Point that prevented data from being logged
	2020 Mar 14	2020 Mar 15	Power failure at East Point that prevented data from being logged

Station	Start	End	Explanation for gaps in acoustic data
	2020 Mar 17	2020 May 25	Large boulder crushed underwater cable during a storm, new cable and mooring deployed 25 May
	2020 Jun 17	2020 Jun 23	Loss of communications 17 Jun, issues with logging computer at East Point 20–22 Jun, repairs completed 22 Jun
	2020 Jul 7	2020 Jul 22	Old ONC Pepwave router failure, maintenance attempted 16 Jul and equipment replaced 22 Jul
	2020 Aug 20	2020 Aug 21	Reason unknown-both wav and FFT files missing
	2020 Sep 23	2020 Sep 23	System maintenance at East Point
	2020 Oct 1	2020 Oct 2	System at East point down to replace East point mooring, which prevented logging of Monarch Head data
	2020 Dec 21	2020 Dec 24	Storm knocked out power-new UPS allowed 36 h of additional data collection

The automated detector used to find killer whale, humpback whale, and Pacific white-side dolphin vocalizations is described in Moloney et al. (2014) and Dewey et al. (2015). In short, a detector is a recognition algorithm that identifies sounds with specific features in acoustic data. This is possible because the species of interest produce signals that have relatively stable durations, bandwidth and shape. Figure 2 shows the various processing steps of the detector. The killer whale detector does not differentiate between different ecotypes or populations of killer whales (e.g., Southern Resident, Northern Resident, or Biggs killer whales). This secondary level of analysis would require a trained analyst, which was not possible for this analysis due to time constraints.

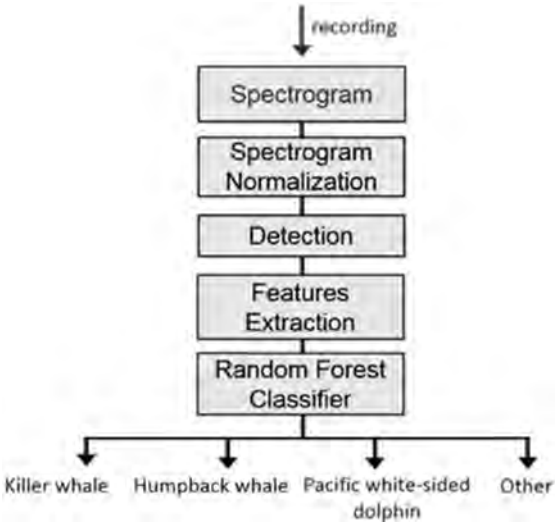

Figure 2. The process for automatic detections of killer whales, humpback whales, and Pacific white-side dolphins vocalizations.

The algorithm first calculated the spectrogram (signal intensity versus time and frequency) and normalized this across each frequency band to emphasize frequency bins with energy above the background. Next, the spectrogram was segmented to detect acoustic events between 10 Hz and 8 kHz where most of the energy from the signals of interest lies. The events are detected when signal amplitude in the normalized spectrogram exceeds a defined minimum threshold. For each identified event, a set of 40 features representing salient characteristics of the spectrogram were extracted, several of which were calculated following Fristrup and Watkins (1993) and Mellinger and Bradbury (2007). The features were based on the spectrogram, frequency envelope, and amplitude envelope of the signal.

Extracted features for each detected signal were presented to a classifier to determine the class of the sound detected. The classification was performed using a random forest classifier (Breiman 2001), which was trained using several thousands of manually annotated vocalizations in recordings collected at different locations in British Columbia (Mouy et al. 2015). The random forest was defined with the following classes: “killer whale”, “humpback whale”, “Pacific white-side dolphin”, “fish”, and “other”. Figure 3 illustrates the key processing steps of the detector on a recording that contained killer whale vocalizations.

All automated detections from killer whale, humpback whale, and Pacific white-sided dolphin vocalizations were manually verified by an experienced analyst using JASCO’s PAMview. All false detections for these species were excluded from the figures in this report.

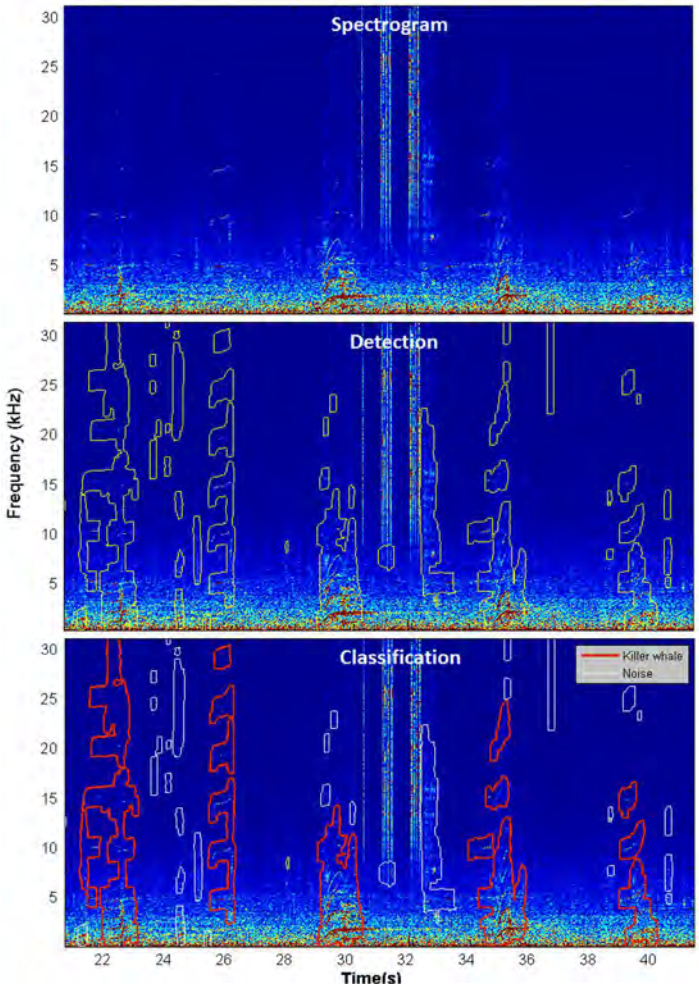

Figure 3. Key processing steps of the detector. Top panel: Spectrogram with killer whale vocalizations. Middle panel: Acoustic events detected in the spectrogram. Bottom panel: Killer whale vocalizations classified using a random forest classifier.

Validated detector results are displayed per station, including all species. This allows for a visual representation of temporal occurrence between stations. The monthly results for validated detections per species are presented in Appendix A for East Point and Appendix B for Monarch Head. Results are presented in the following three formats:

- Pie charts of the relative number of automatic vocalizations detections by species.
- Graphs showing the number of detections for each hour and per day for each species. All graphs are in local time unless otherwise indicated.
- Spectrograms showing how the frequency of animal vocalizations varied in time.

3. RESULTS

The marine mammal results presented in this report represent only those detections that were manually validated by an experienced analyst. Killer whales and humpback whales were the only marine mammals reported on for this data set at both Monarch Head and East Point. No detections of Pacific white-sided dolphin calls were validated at either station during the study period.

Table 4 lists the validated detection counts of species vocalizations at East Point and Monarch Head stations in 2020. The results per station are outlined below in Sections 3.1 and 3.2.

Table 4. Validated detection counts of marine mammals at each station.

Species	East Point	Monarch Head
Killer whales	3805	2783
Humpback whales	1344	1983
Pacific white-sided dolphins	0	0

3.1. Monarch Head

Throughout the 2020 recording period, killer whales were detected on 36 days throughout all seasons, with increased detection counts from 4 Sep to 25 Oct, and 11 Dec to 29 Dec (Figure 4 and Table 5). Daily call counts did not exceed 500. Humpback whale detections were concentrated over 10 days with a few days in late November, but calls were detected also through 29 Dec.

Table 5. Number of detection days for each marine mammal present at Monarch Head.

Species	Number of detection days
Killer whales	36
Humpback whales	10

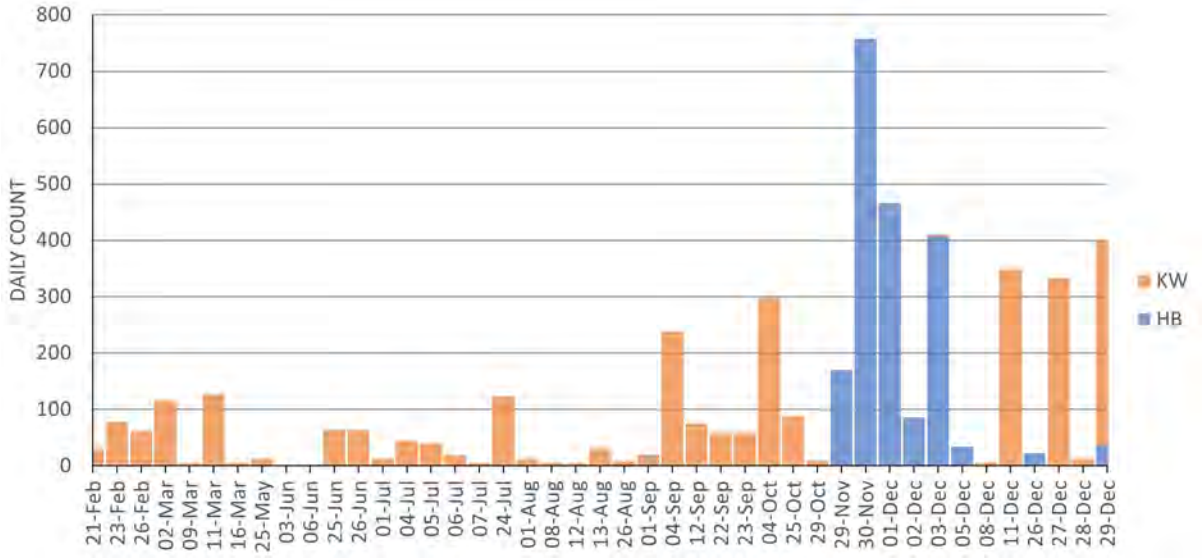

Figure 4. Validated killer whale and humpback whale call detections on days with at least one detection at Monarch Head during the recording period.

3.2. East Point

Validated killer whale call detections were higher at East Point than Monarch head, and killer whales were present throughout all seasons. An unusually large number of killer whale detections (1200) occurred on 25 Mar, but daily call detections were otherwise less than 300. Killer whale calls were detected on 42 days of the recording period (Figure 5 and Table 6). Humpback whale detections at East Point were similar to those at Monarch Head. These were concentrated over 6 days in early December, and calls were detected through 14 Dec for a total of 9 days with validated detections.

Table 6. Number of detection days for each marine mammal present at East Point.

Species	Number of detection days
Killer whales	42
Humpback whales	9

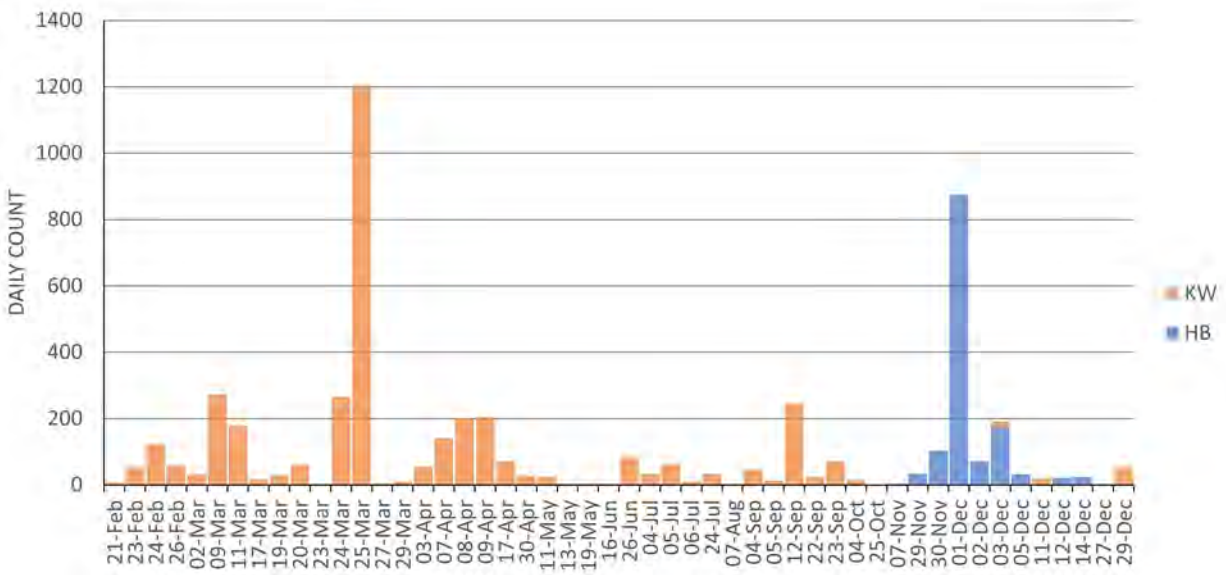

Figure 5. Validated killer whale and humpback whale call detections on days with at least one detection at East Point during the recording period.

4. DISCUSSION

The marine mammal acoustic detection results presented in this report provide an index of acoustic occurrence for each species. Although they can be used to describe the relative abundance of a species across the study area, a number of factors influence the detectability of the targeted signals. While acoustic detection does indicate presence, an absence of detections does not necessarily indicate absence of animals; that can be due to lack of vocalizations by individuals near the acoustic recorders, masking of signals by environmental or anthropogenic noise sources, or a combination of these factors. Different sound propagation environments and between seasons will affect the detection range of a given signal over time and therefore influence the number of detected signals. Seasonal variations in calling behaviour may falsely suggest changes in occurrence. Therefore, the acoustic occurrence of each species across stations is discussed in light of environmental, anthropogenic and biological factors influencing the detectability of the targeted acoustic signals.

Overall, the number of validated detection counts for killer whales was higher at both East Point and Monarch Head in 2020 than in 2018–2019 (Table 7). Killer whales were detected on 42 days at East Point (Table 6) and 36 days at Monarch Head (Table 5). Killer whale presence was expected throughout the recording period based on previous results from this study area and their known distribution. For this analysis, killer whale detections were not specified to the ecotype level, which would require a secondary level of analysis. However, there is a relatively high occurrence of SRKW in the Boundary Pass study area. Both SRKW and Bigg's are observed on the nearby Boundary Pass listening station and these same individuals are likely being detected by the Monarch Head and East Point recorders.

SRKW population is found from Monterey Bay, CA, to Chatham Strait, south eastern Alaska, with a core range in the waters off southern Vancouver Island. They comprise three pods: J, K, and L (Centre for Whale Research 2021). Annual population updates occur on 1 Jul and 3 Dec each year and as of December 2017, the SRKW population totals 76 whales: J pod (23), K pod (18), and L pod (35) (Centre for Whale Research 2021).

Table 7. Yearly counts of manually validated killer whale and humpback whale call detections at each station.

Species	East Point			Monarch Head		
	2018	2019	2020	2018	2019	2020
Killer whale	2862	2250	3805	2577	1908	2783
Humpback whale	2212	131*	1344	4327	1122	1983

* East Point hydrophone had data issues during fall 2019, which likely caused an underrepresentation of humpback call counts.

It is important to note that several months of data were unavailable at East Point during fall 2019, likely reducing call counts for both killer whale and humpbacks then (Table 8). Since most humpback call detections occur in the fall, this is almost certainly the reason for much lower humpback calls for 2019 at East Point. The number of days with acoustic data were much lower in 2019 at both stations, making comparisons between years challenging (Table 8). Overall, there was a higher occurrence of killer whales at East Point, but the differences are not sufficient to draw conclusions about site preference. The large number of killer whale detections at East Point in 2020 is partly attributed to a large number of detections on a single day (1200) that occurred 25 March.

Table 8. Yearly counts of days with acoustics data at each station.

Station	2018	2019	2020
East Point	300	233	292
Monarch Head	234	178	237

Humpback whale detections were lower at East Point in 2020 than 2018 but may be described by natural variability. A proper comparison of 2020 results cannot be made with those from 2019, as data were unavailable during the highest detection count months for humpback whales. Similar detection counts were observed between 2019 and 2020 for humpback whales at Monarch Head. This may be due to a more favourable and higher productivity area. The current results show humpback whales are most commonly detected on the SIMRES hydrophones in November and December, and that is also the case at the Boundary Pass underwater listening station. Interestingly, humpback whales are frequently observed travelling close to shore along East Point in summer, but those whales seemingly do not generate detectable sounds. Humpback whale acoustic occurrence is expected to peak during winter when males sing. This feature of their calling behaviour agrees with the observations of the 2017–2018 and 2018–2019 data sets (Frouin-Mouy et al. 2020, Mouy et al. 2020). Singing outside of known low-latitude breeding grounds has similarly been reported elsewhere in the North Pacific and in other high-latitude feeding areas or migratory routes around the globe and seems to be a standard practice for the species (Baker et al. 1985, McSweeney et al. 1989, Norris et al. 1999, Stanistreet et al. 2013, Kowarski et al. 2019, Magnúsdóttir and Lim 2019, Ryan et al. 2019). Song production outside of breeding grounds may be important for song learning of this culturally transmitted behaviour (Payne et al. 1983, Garland et al. 2013, Kowarski et al. 2019, Magnúsdóttir and Lim 2019), and the timing of onset may be driven by physiological changes caused by seasonal fluctuations in hormone levels (Cates et al. 2019, Kowarski et al. 2019). It is yet unclear whether successful mating occurs outside of the breeding grounds. The apparent diel trend in humpback whale vocal behaviour observed here and in previous SIMRES and Boundary Pass acoustic data sets has similarly been reported elsewhere including off eastern Canada (Kowarski et al. 2018, Kowarski et al. 2019), Mexico (Cholewiak 2008), Brazil (Sousa-Lima and Clark 2008), and Angola (Cerchio et al. 2014).

It is important to note that the low counts of humpback whale detections during summer does not necessarily represent species are less likely to be in the area, and as noted above there are

frequent summer visual detections of this species very near the hydrophone locations. Validated humpback whale call detections were only present on 10 days of the recording period. The detector misclassified humpback whale vocalizations during summer that were actually harbour seal vocalizations. An analysis method that implies detector performance would be warranted for future studies along with developing a harbour seal detector to further investigate multiple species occurrence.

The Boundary Pass recorder does not typically detect Pacific white-sided dolphins in this area. However, Pacific white-sided dolphins have been recorded year-round off BC and can therefore be considered permanent residents in this area, although they may not be in close proximity to the recording stations or do not vocalize frequently while in Boundary Pass. As previously described, there are a number of factors influencing why these species vocalizations may not be present in the data (e.g., proximity to recorders, masking).

This study contributes important information on the occurrence of several species in the Boundary Pass for ongoing research required to investigate factors driving the distributions of marine mammals, specifically SRKW. The noise effects of anthropogenic activities (i.e., vessels) on marine mammals in these areas of overlap are evident, primarily in the form of communication masking or habitat displacement. JASCO validated marine mammal vocalizations in a real-time system (PAMview), which does not allow for detector performance to be calculated. The limitation of being unable to control the data quality can influence how well the detectors perform. Overall, continued monitoring programs, including long-term acoustic monitoring and visual observations, will allow for continued tracking of marine mammal presence. The implementation and expansion of an ISZ off Saturna Island is expected to benefit marine mammal use of the near-shore areas, including its use by SRKW.

5. CONCLUSION

Over 9000 marine mammal detections were validated in the acoustic data for the ~10 month study period. Over 50% of these were from killer whales, and the detections occurred throughout the study period for maximum of 42 days at East Point (Table 6). The remaining detections were from humpback whales, primarily occurring during November and December. Humpbacks calls were detected on a maximum of 10 days of the recording period (Table 5). Killer whale occurrence was higher at East Point, whereas humpback whales had higher detection counts at Monarch Head.

From this study, the results suggest that when comparing the validated detectors for killer whales in 2020 to the previous SIMRES data sets (2018–2019), the detection counts have increased. This may be from multiple contributing factors such as better data quality allowing for higher detector performance, increased use of habitat by SRKW, and/or less underwater noise pollution from vessels. Continued long-term acoustic monitoring of these areas will allow for continued observations on species occurrence.

The environmental, anthropogenic, and noise-related factors that may influence detection patterns at each station should be investigated further. An analysis approach that allows for detector performance, creating and adding a separate pinniped detector, along with an increased scope and timeline to determine killer whale ecotypes is warranted for future study analysis. This would allow for specific focus on SRKW occurrence, as the species of interest for TC and SIMRES in the Boundary Pass area.

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APPENDIX A. SPECIES SUMMARY PER STATION

Appendices A.1 and A.2 outline the occurrence of killer whales and humpback whales at Monarch Head and East Point.

A.1. Killer Whales

A.1.1. East Point

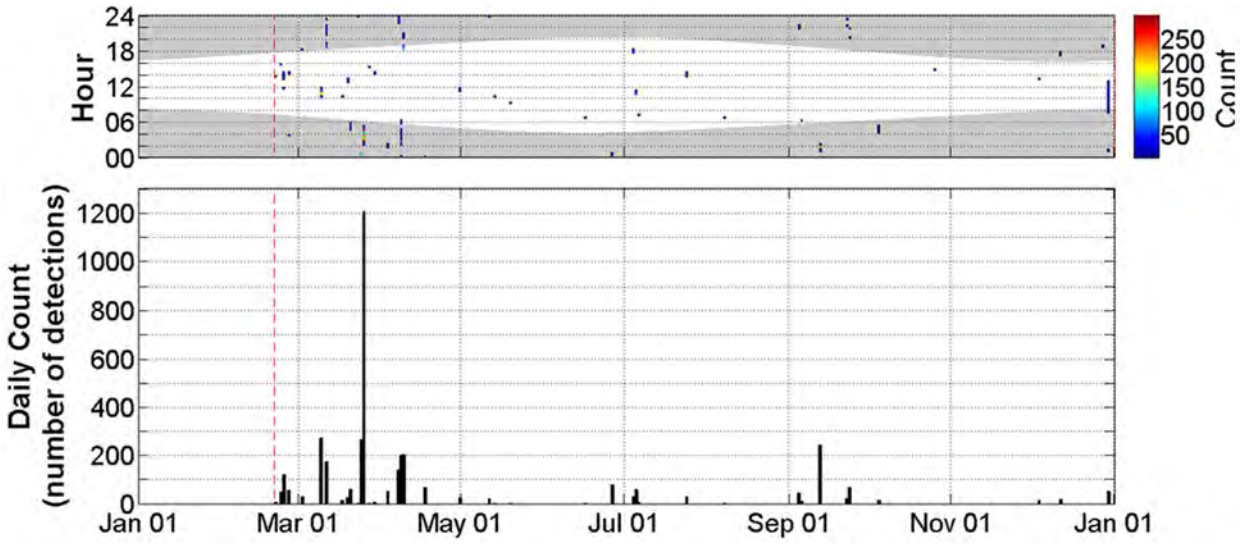

Figure A-1. Killer whale vocalizations at East Point station for 2020: Hourly and daily detection counts (PST, UTC-8h). Grey areas indicate darkness period.

A.1.2. Monarch Head

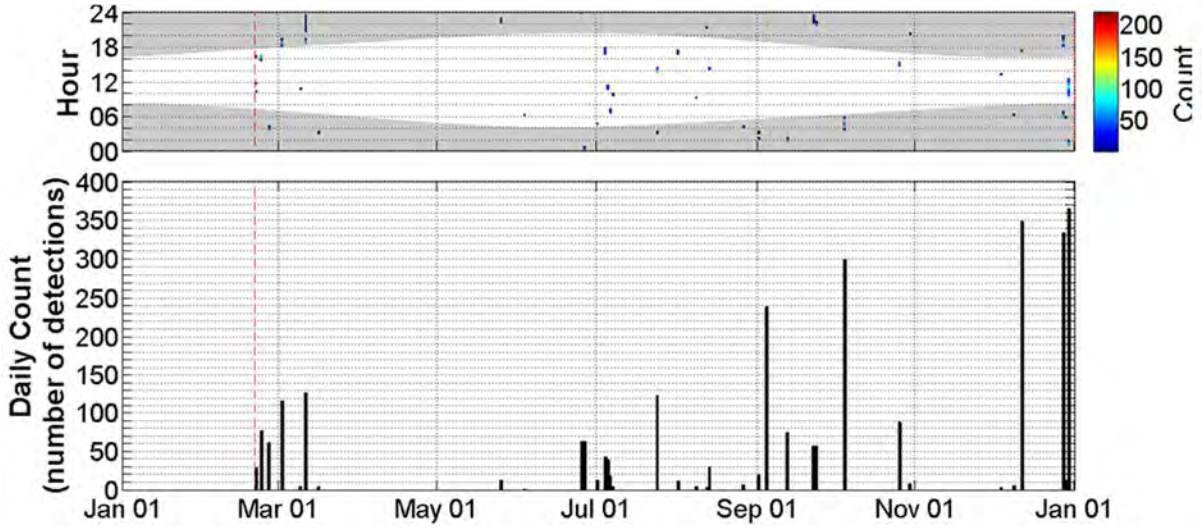

Figure A-2. Killer whale vocalizations at Monarch Head station for 2020: Hourly and daily detection counts (PST, UTC-8h). Grey areas indicate darkness period.

A.2. Humpback Whales

A.2.1. East Point

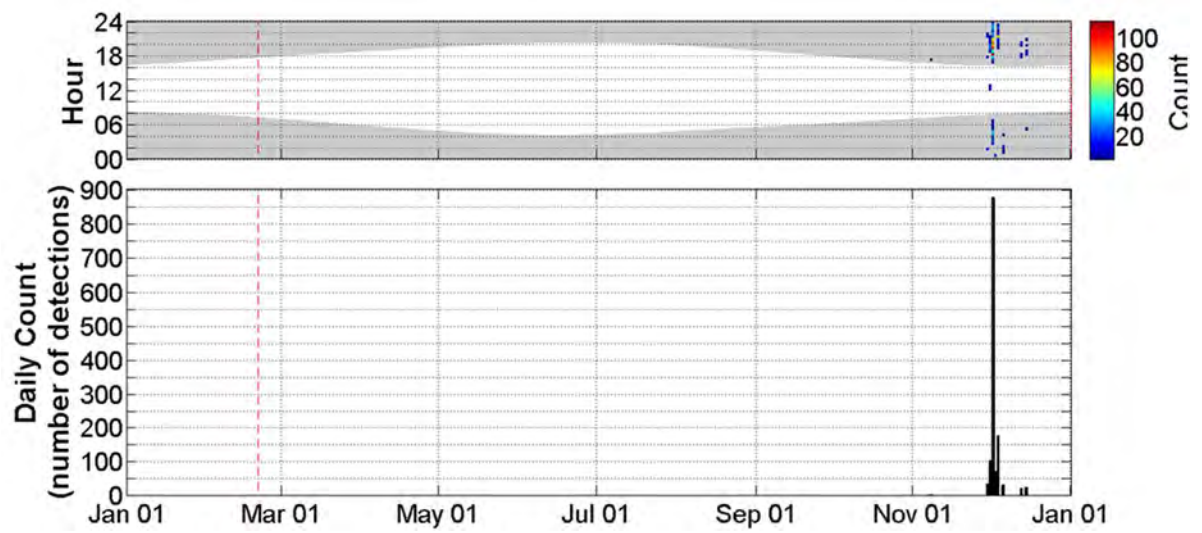

Figure A-3. Humpback whale vocalizations at East Point station for 2020: Hourly and daily detection counts (PST, UTC-8h). Grey areas indicate darkness period.

A.2.2. Monarch Head

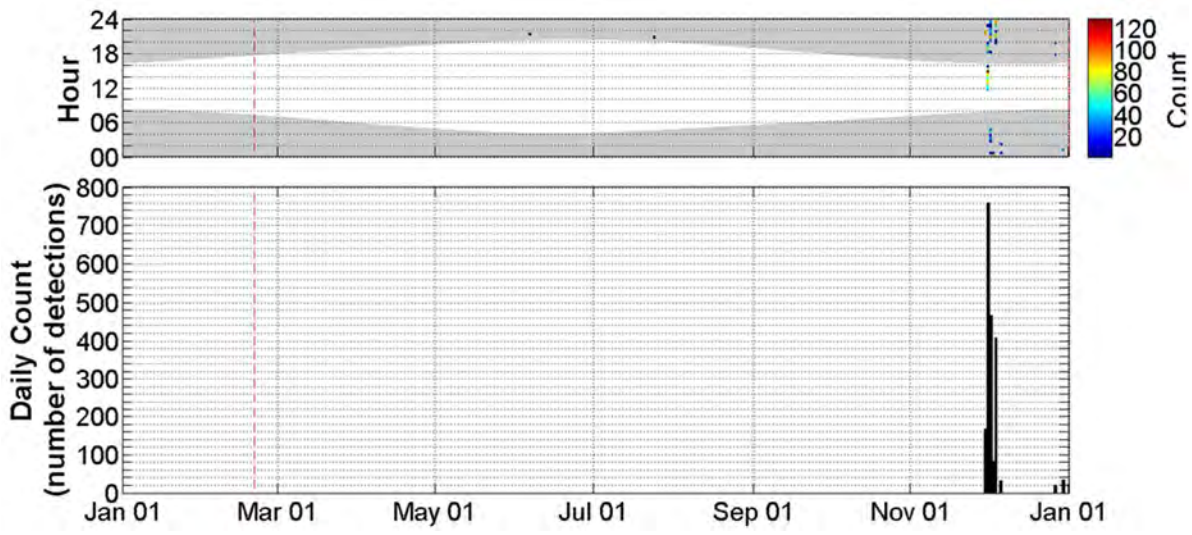

Figure A-4. Humpback whale vocalizations at Monarch Head station for 2020: Hourly and daily detection counts (PST, UTC-8h). Grey areas indicate darkness period.

APPENDIX B. MONARCH HEAD MONTHLY RESULTS

Results of marine mammal detections made on SIMRES's Monarch Head hydrophone are provided here, segregated by month.

B.1. February 2020

B.1.1. Relative Vocalization Detections by Species

A total of 170 killer whale vocalizations were reported by the automated detector from 21–29 Feb 2020 at Monarch Head station. No Pacific white-sided dolphins or humpback whales were detected at Monarch Head during this period. Figure B-1 shows the proportion of detections by species for this period.

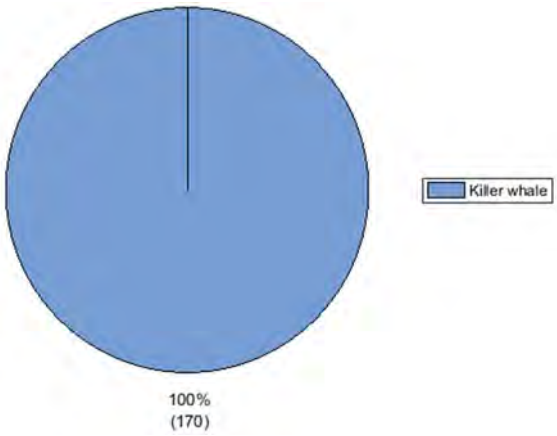

Figure B-1. Relative vocalization detections for 21–29 Feb 2020 at Monarch Head.

B.1.2. Killer Whales

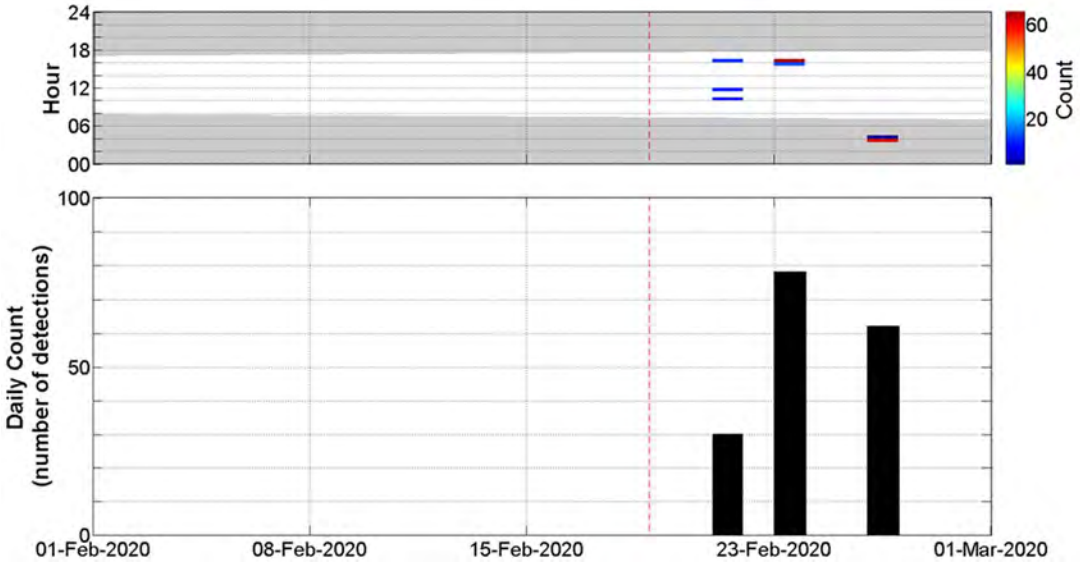

Figure B-2. Killer whale vocalizations at Monarch Head station for February 2020: Hourly and daily detection counts (PST, UTC-8h). Grey areas indicate darkness period.

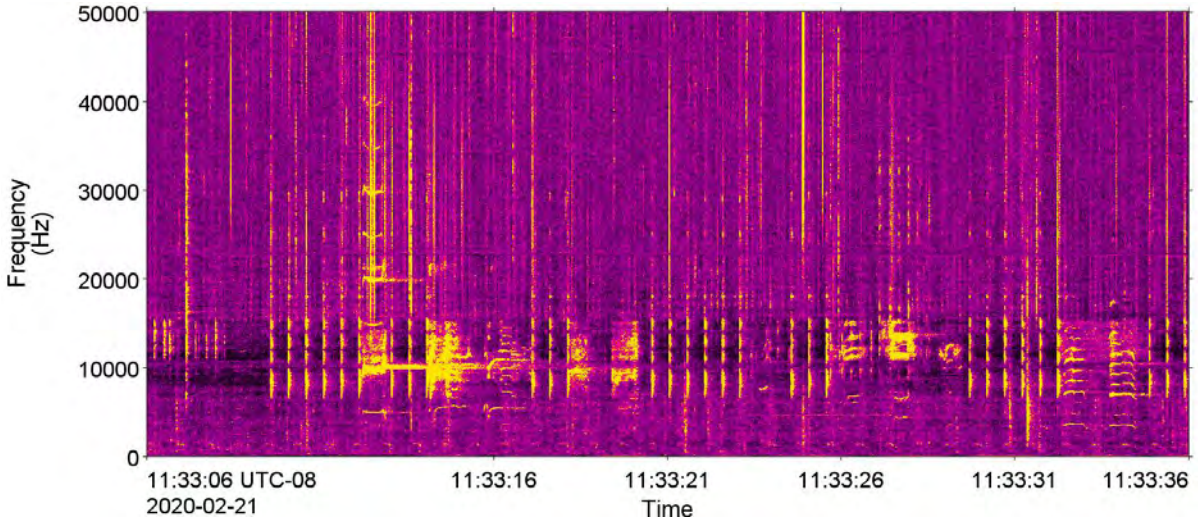

Figure B-3. Killer whales: Spectrogram of vocalizations at Monarch Head station on 21 Feb 2020 (PST, UTC-8h).

B.2. March 2020

B.2.1. Relative Vocalization Detections by Species

A total of 253 killer whale vocalizations were reported by the automated detector from 1–18 Mar 2020 at Monarch Head station. No Pacific white-sided dolphins or humpback whales were detected at Monarch Head during this period. Figure B-4 shows the proportion of detections by species for this period.

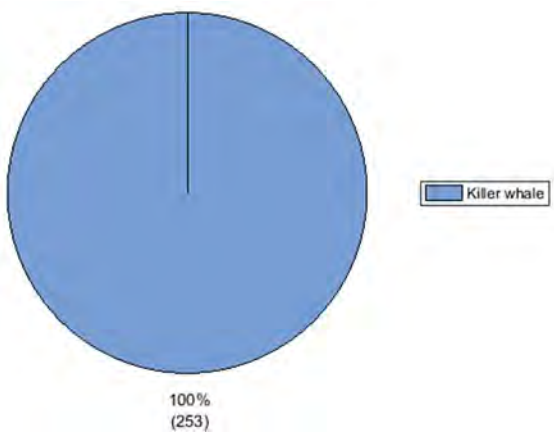

Figure B-4. Relative vocalization detections for 1–18 Mar 2020 at Monarch Head.

B.2.2. Killer Whales

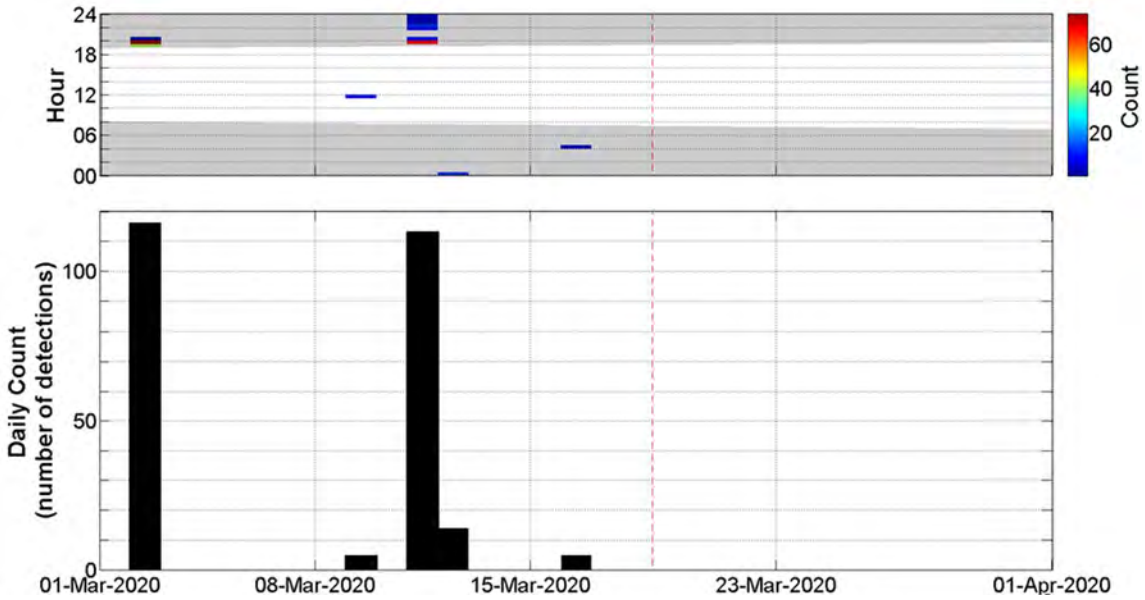

Figure B-5. Killer whale vocalizations at Monarch Head station for March 2020: Hourly and daily detection counts (PDT, UTC-7h). Grey areas indicate darkness period.

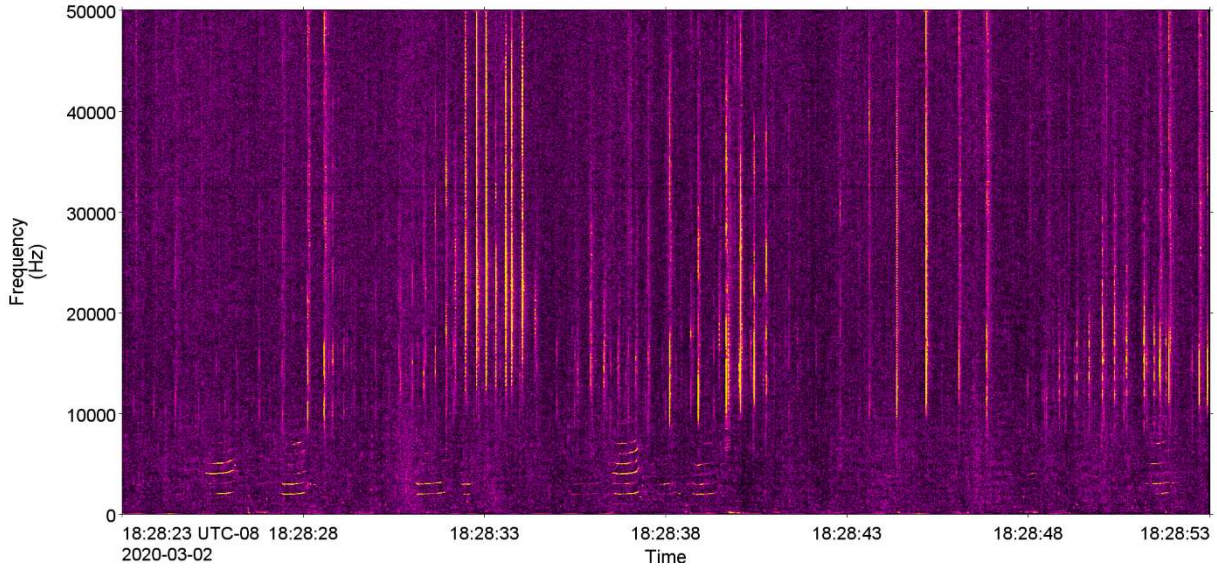

Figure B-6. Killer whales: Spectrogram of vocalizations at Monarch Head station on 2 Mar 2020 (PDT, UTC-7h).

B.3. April 2020

No acoustic data were available for this month (see Section 2 for details).

B.4. May 2020

B.4.1. Relative Vocalization Detections by Species

A total of 13 killer whale vocalizations were reported by the automated detector from 25–31 May 2020 at Monarch Head station. No Pacific white-sided dolphins or humpback whales were detected at Monarch Head during this period. Figure B-7 shows the proportion of detections by species for this period.

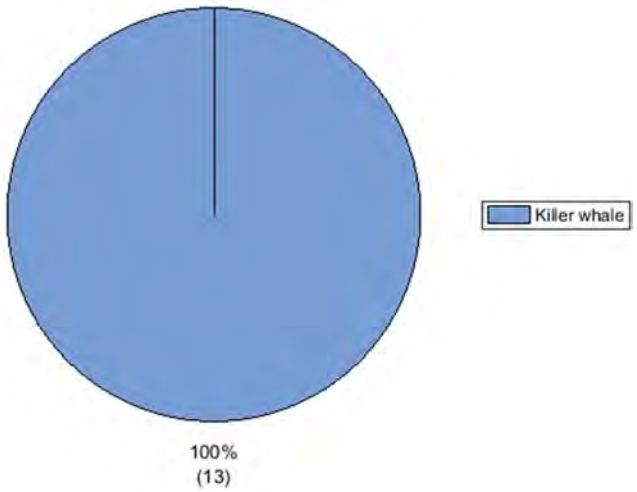

Figure B-7. Relative vocalization detections for 25–31 May 2020 at Monarch Head.

B.4.2. Killer Whales

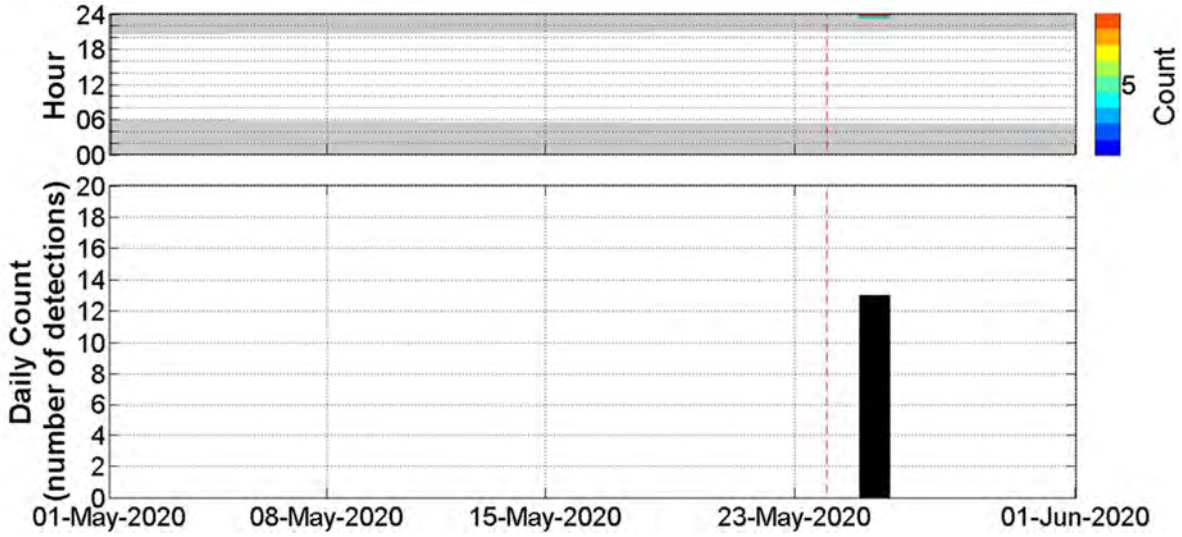

Figure B-8. Killer whale vocalizations at Monarch Head station for May 2020: Hourly and daily detection counts (PDT, UTC-7h). Grey areas indicate darkness period.

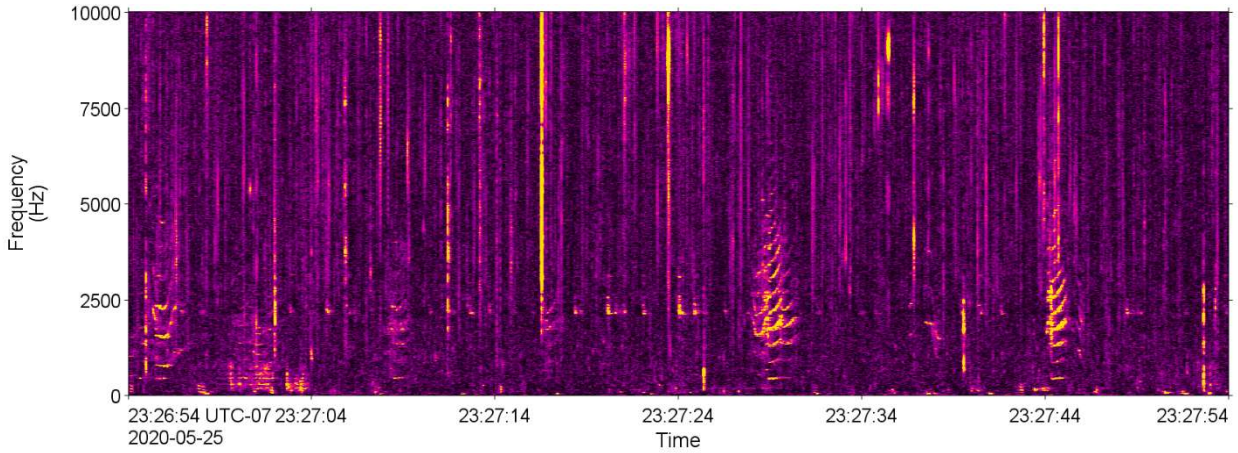

Figure B-9. Killer whales: Spectrogram of vocalizations at Monarch Head station on 25 May 2020 (PDT, UTC-7h).

B.5. June 2020

B.5.1. Relative Vocalization Detections by Species

A total of 130 killer whale vocalizations and 2 humpback whale vocalizations were reported by the automated detector from 1–30 Jun 2020 at Monarch Head station. No Pacific white-sided dolphins were detected at Monarch Head during this period. Figure B-10 shows the proportion of detections by species for this period.

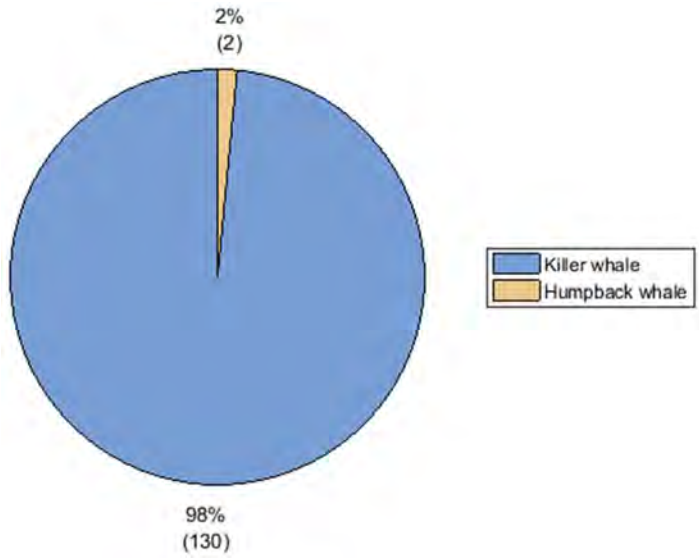

Figure B-10. Relative vocalization detections for 1–30 Jun 2020 at Monarch Head.

B.5.2. Killer Whales

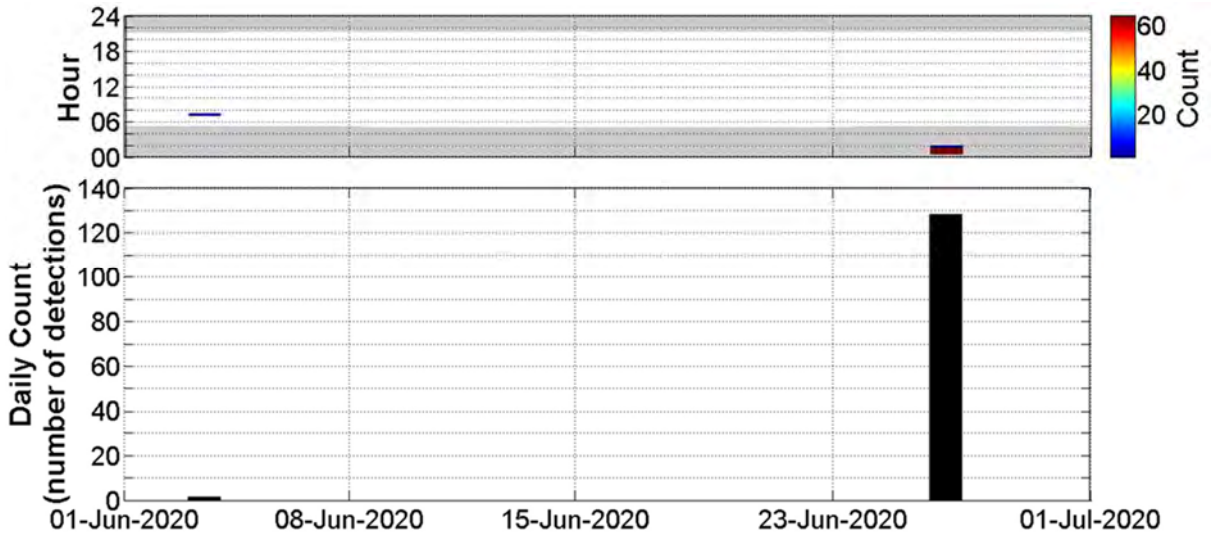

Figure B-11. Killer whale vocalizations at Monarch Head station for June 2020: Hourly and daily detection counts (PDT, UTC-7h). Grey areas indicate darkness period.

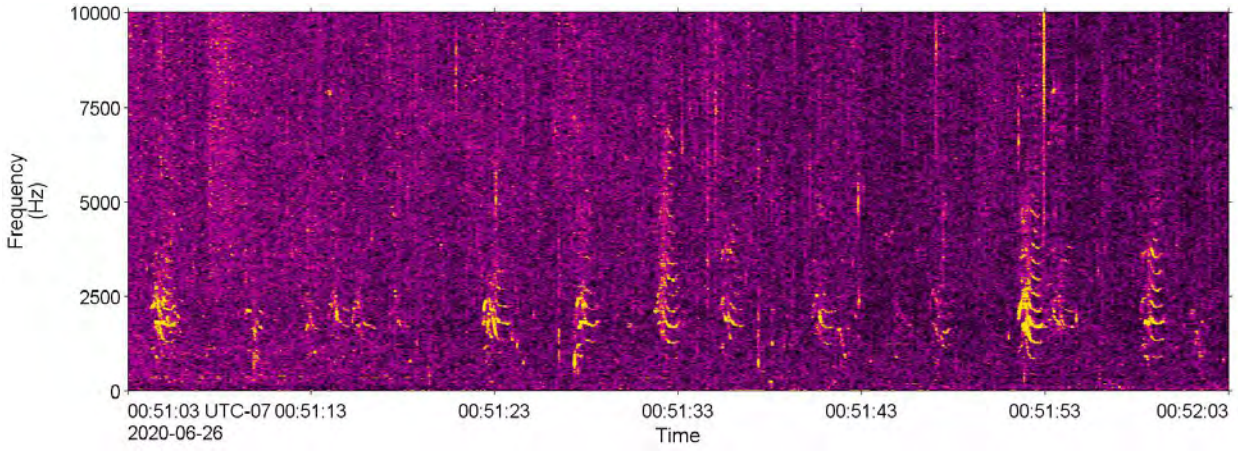

Figure B-12. Killer whales: Spectrogram of vocalizations at Monarch Head station on 26 Jun 2020 (PDT, UTC-7h).

B.5.3. Humpback Whales

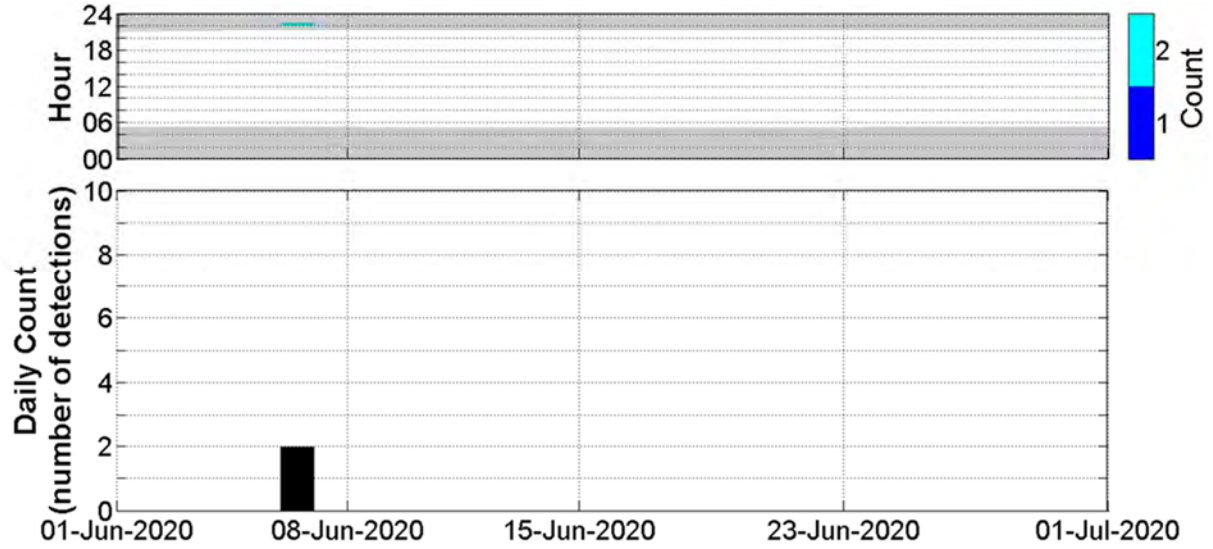

Figure B-13. Humpback whale vocalizations at Monarch Head station for June 2020: Hourly and daily detection counts (PDT, UTC-7h). Grey areas indicate darkness period.

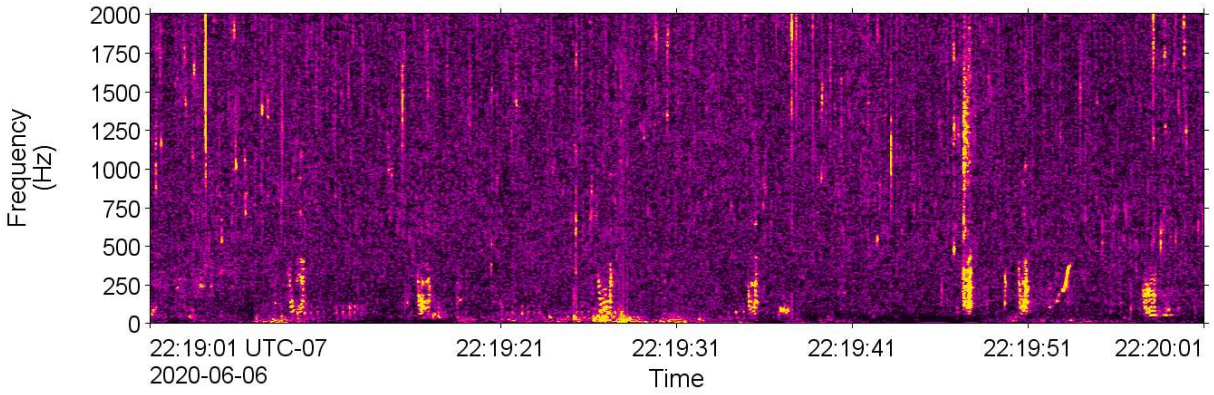

Figure B-14. Humpback whales: Spectrogram of vocalizations at Monarch Head station on 6 Jun 2020 (PDT, UTC-7h).

B.6. July 2020

Acoustic data from Monarch Head from 8–23 Jul 2020 were not available for analysis.

B.6.1. Relative Vocalization Detections by Species

A total of 244 killer whale vocalizations and 1 humpback whale vocalizations were reported by the automated detector from 1–7 and 24–31 Jul 2020 at Monarch Head station. No Pacific white-sided dolphins were detected at Monarch Head during this period. Figure B-15 shows the proportion of detections by species for this period.

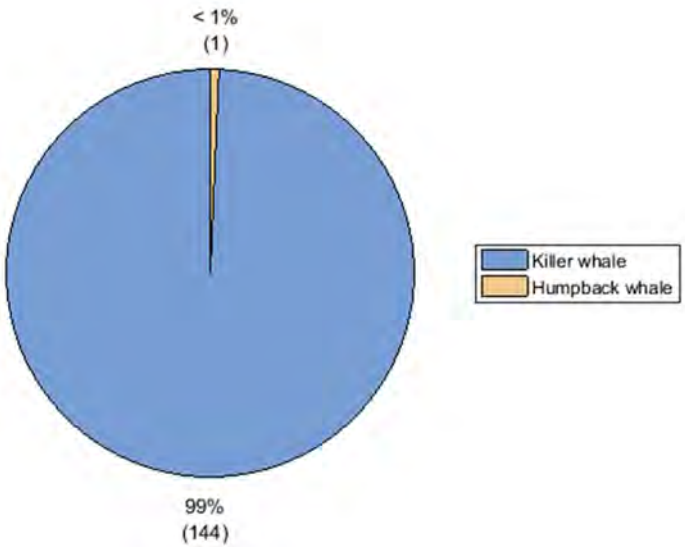

Figure B-15. Relative vocalization detections for 1–7 and 24–31 Jul 2020 at Monarch Head.

B.6.2. Killer Whales

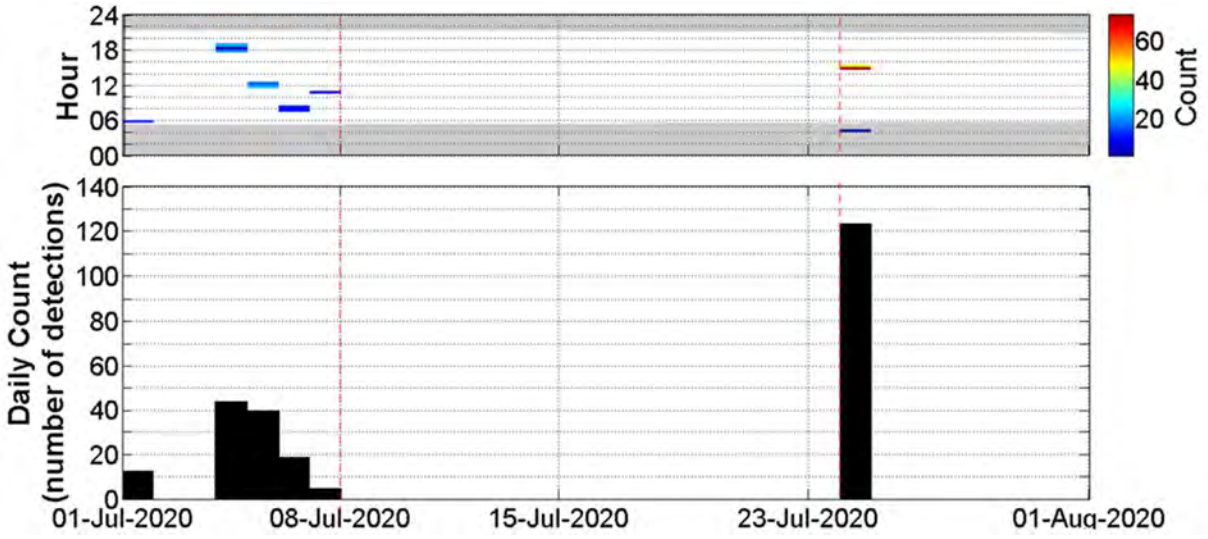

Figure B-16. Killer whale vocalizations at Monarch Head station for July 2020: Hourly and daily detection counts (PDT, UTC-7h). Grey areas indicate darkness period.

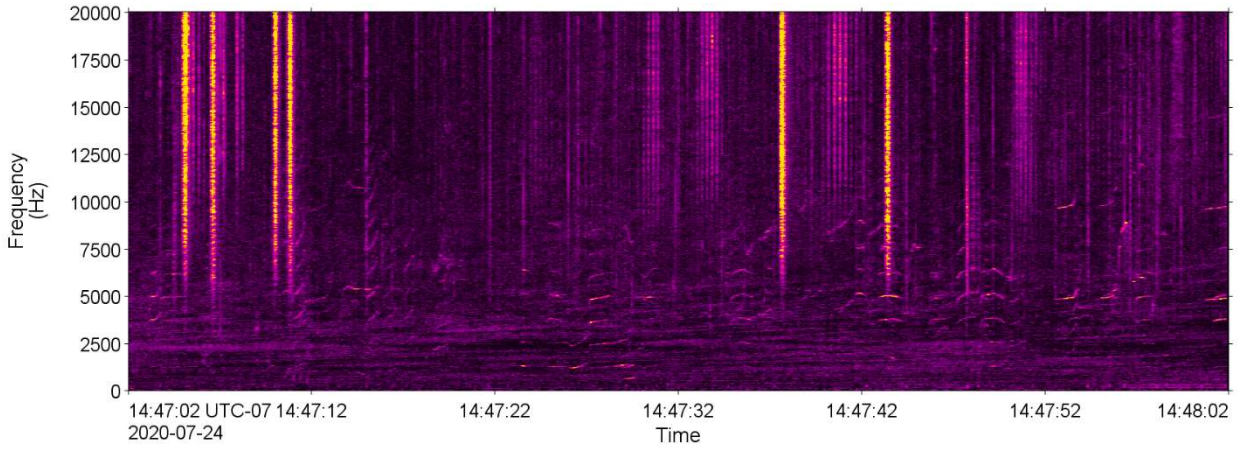

Figure B-17. Killer whales: Spectrogram of vocalizations at Monarch Head station on 24 Jul 2020 (PDT, UTC-7h).

B.6.3. Humpback Whales

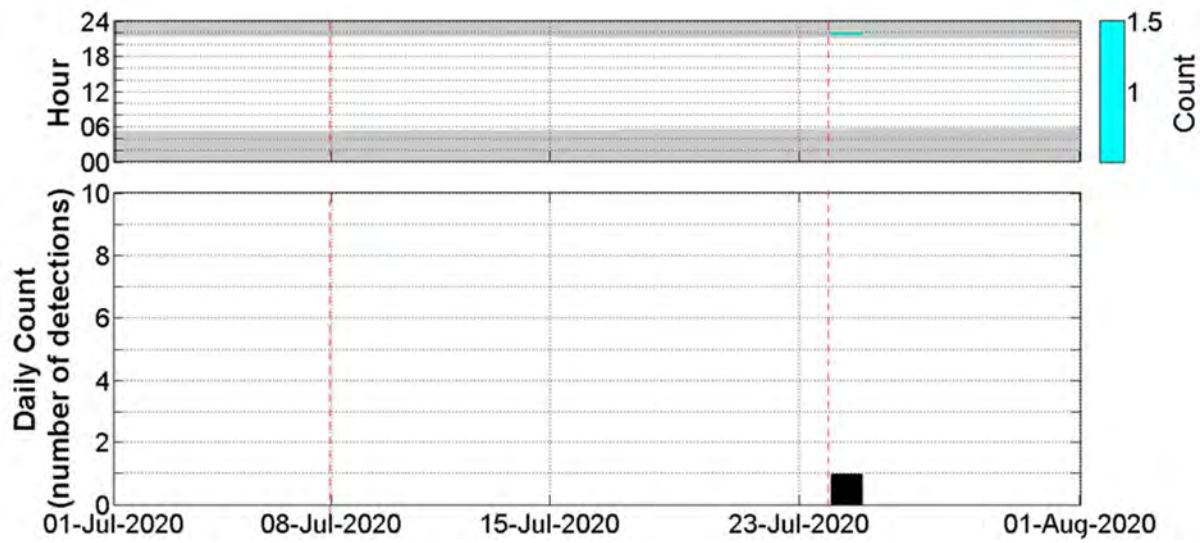

Figure B-18. Humpback whale vocalizations at Monarch Head station for July 2020: Hourly and daily detection counts (PDT, UTC-7h). Grey areas indicate darkness period.

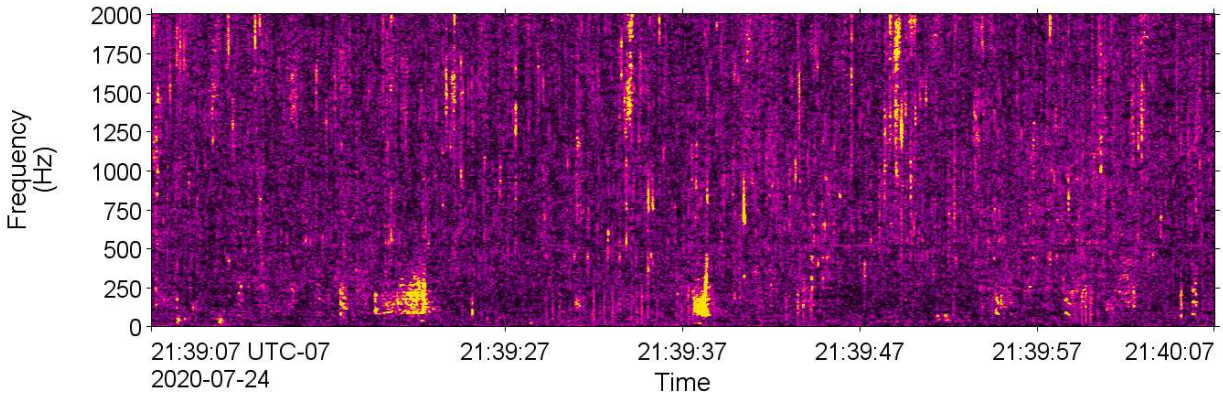

Figure B-19. Humpback whales: Spectrogram of vocalizations at Monarch Head station on 24 Jul 2020 (PDT, UTC-7h).

B.7. August 2020

B.7.1. Relative Vocalization Detections by Species

A total of 60 killer whale vocalizations were reported by the automated detector from 1–31 Aug 2020 at Monarch Head station. No Pacific white-sided dolphins or humpback whales were detected at Monarch Head during this period. Figure B-20 shows the proportion of detections by species for this period.

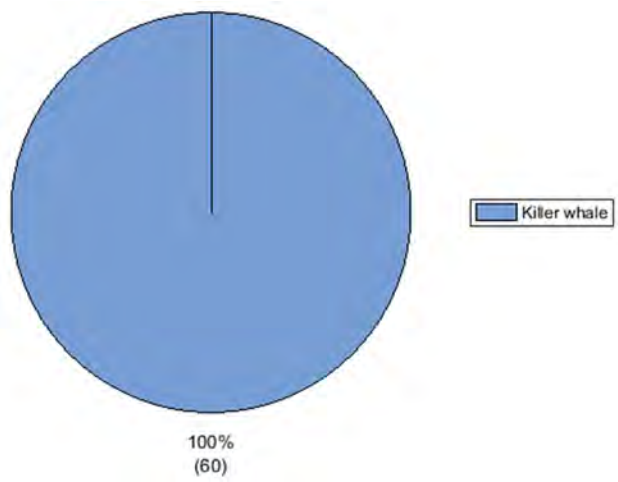

Figure B-20. Relative vocalization detections for 1–31 Aug 2020 at Monarch Head.

B.7.2. Killer Whales

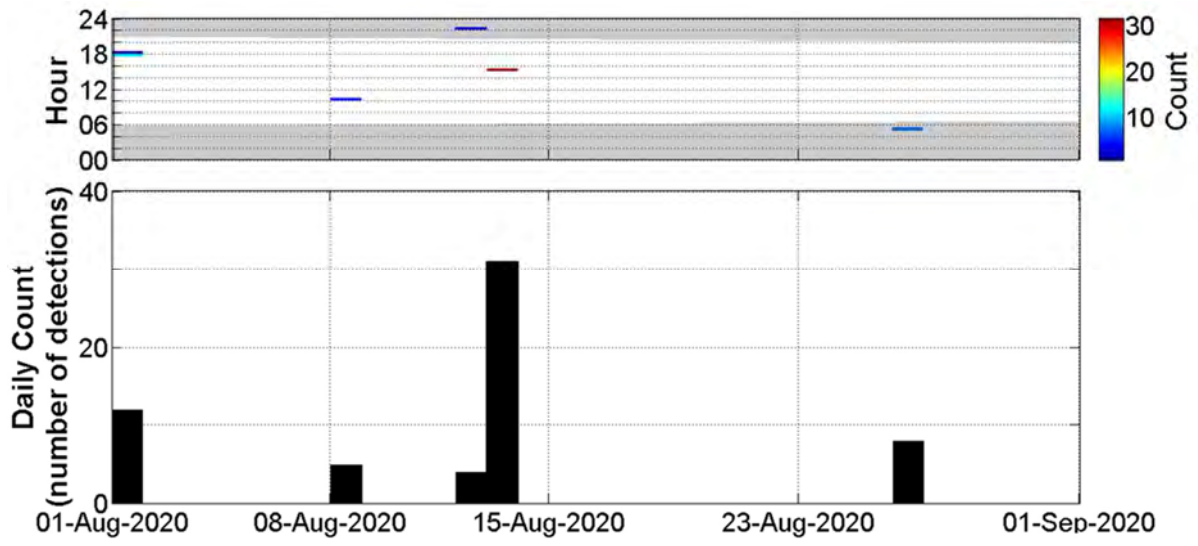

Figure B-21. Killer whale vocalizations at Monarch Head station for August 2020: Hourly and daily detection counts (PDT, UTC-7h). Grey areas indicate darkness period.

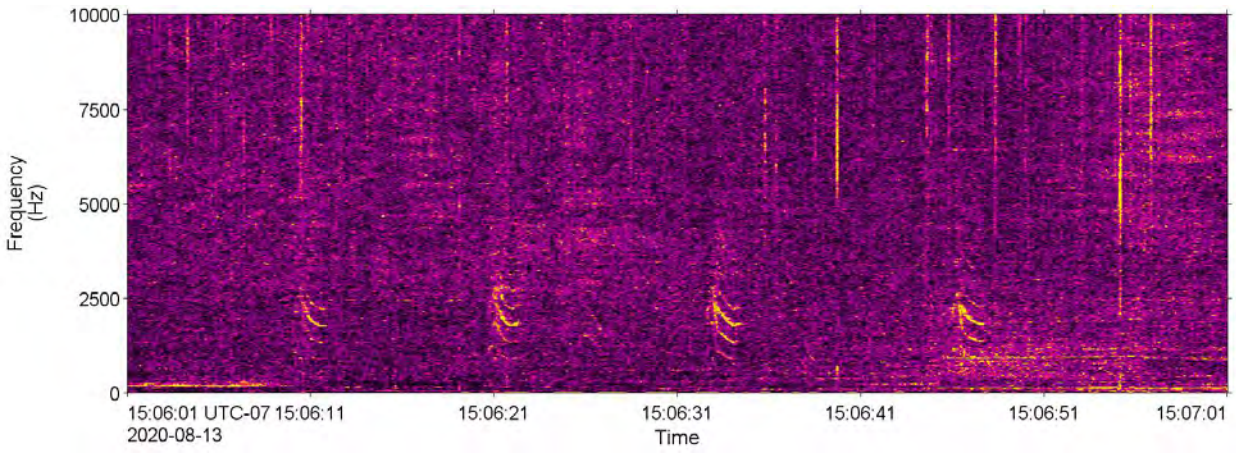

Figure B-22. Killer whales: Spectrogram of vocalizations at Monarch Head station on 13 Aug 2020 (PDT, UTC-7h).

B.8. September 2020

B.8.1. Relative Vocalization Detections by Species

A total of 449 killer whale vocalizations were reported by the automated detector from 1–30 Sep 2020 at Monarch Head station. No Pacific white-sided dolphins or humpback whales were detected at Monarch Head during this period. Figure B-23 shows the proportion of detections by species for this period.

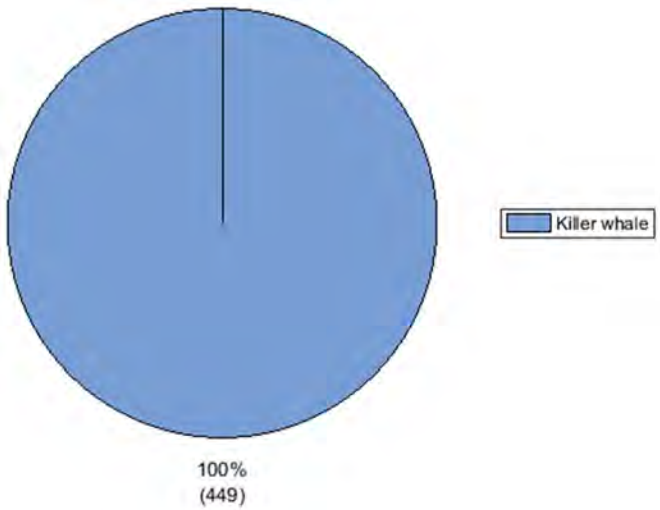

Figure B-23. Relative vocalization detections for 1–30 Sep 2020 at Monarch Head.

B.8.2. Killer Whales

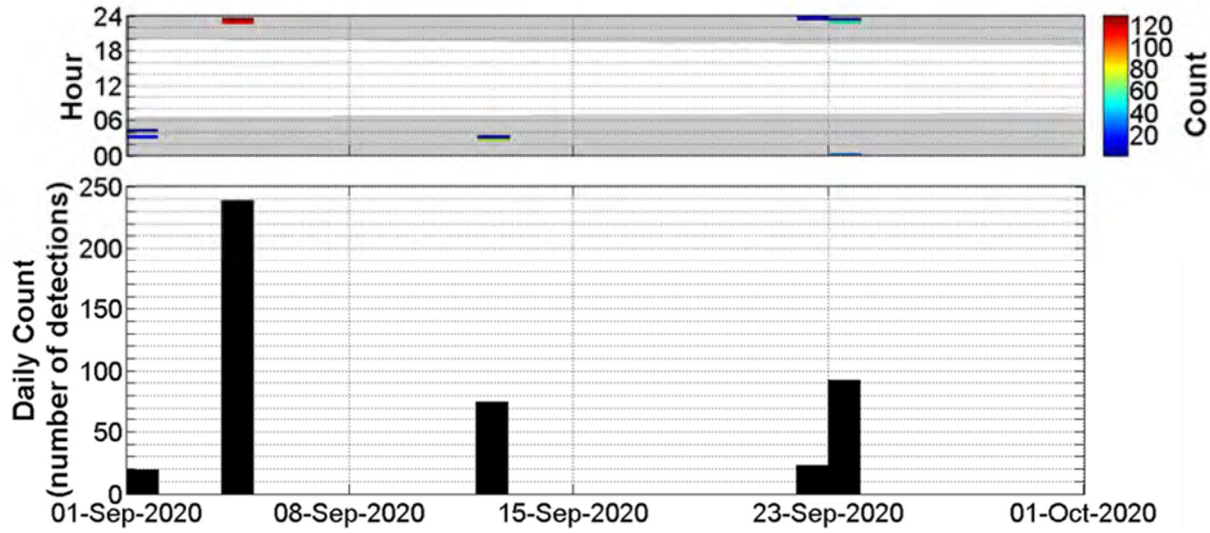

Figure B-24. Killer whale vocalizations at Monarch Head station for September 2020: Hourly and daily detection counts (PDT, UTC-7h). Grey areas indicate darkness period.

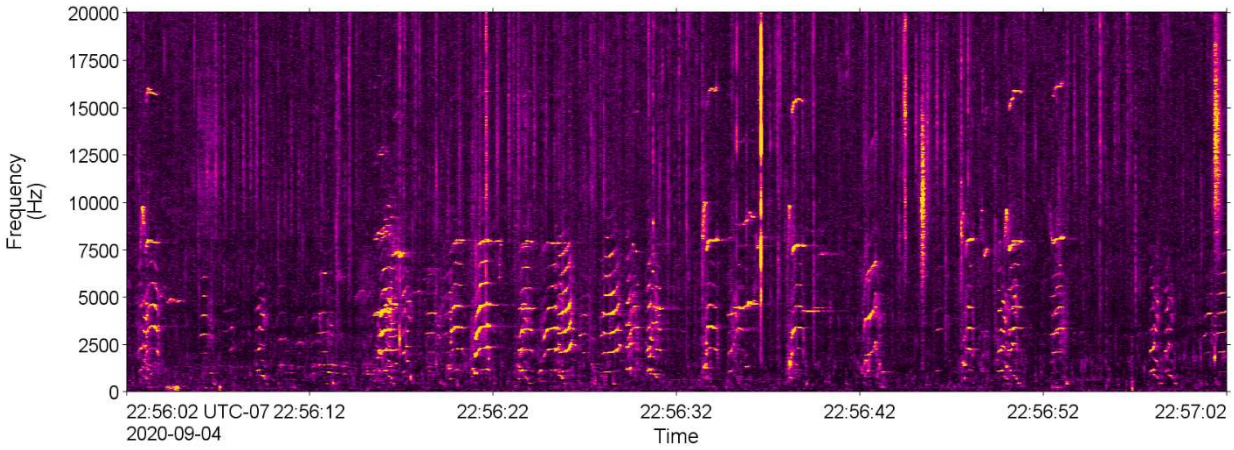

Figure B-25. Killer whales: Spectrogram of vocalizations at Monarch Head station on 4 Sep 2020 (PDT, UTC-7h).

B.9. October 2020

B.9.1. Relative Vocalization Detections by Species

A total of 396 killer whale vocalizations were reported by the automated detector from 1–31 Oct 2020 at Monarch Head station. No Pacific white-sided dolphins or humpback whales were detected at Monarch Head during this period. Figure B-26 shows the proportion of detections by species for this period.

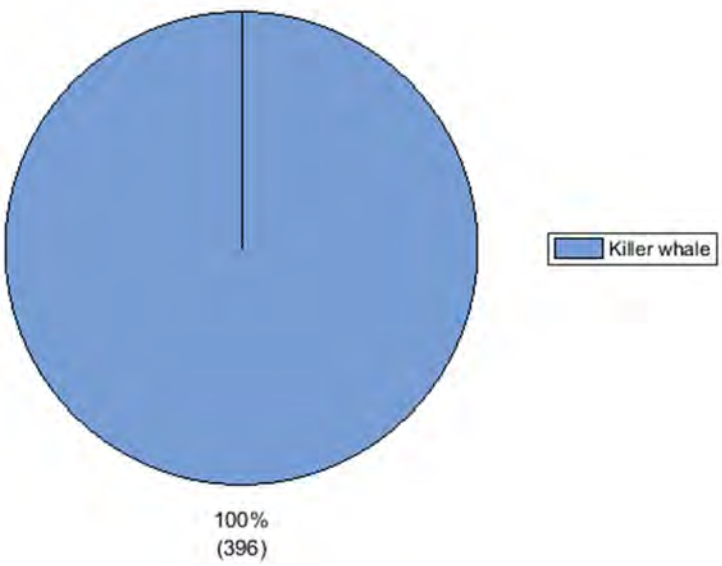

Figure B-26. Relative vocalization detections for 1–31 Oct 2020 at Monarch Head.

B.9.2. Killer Whales

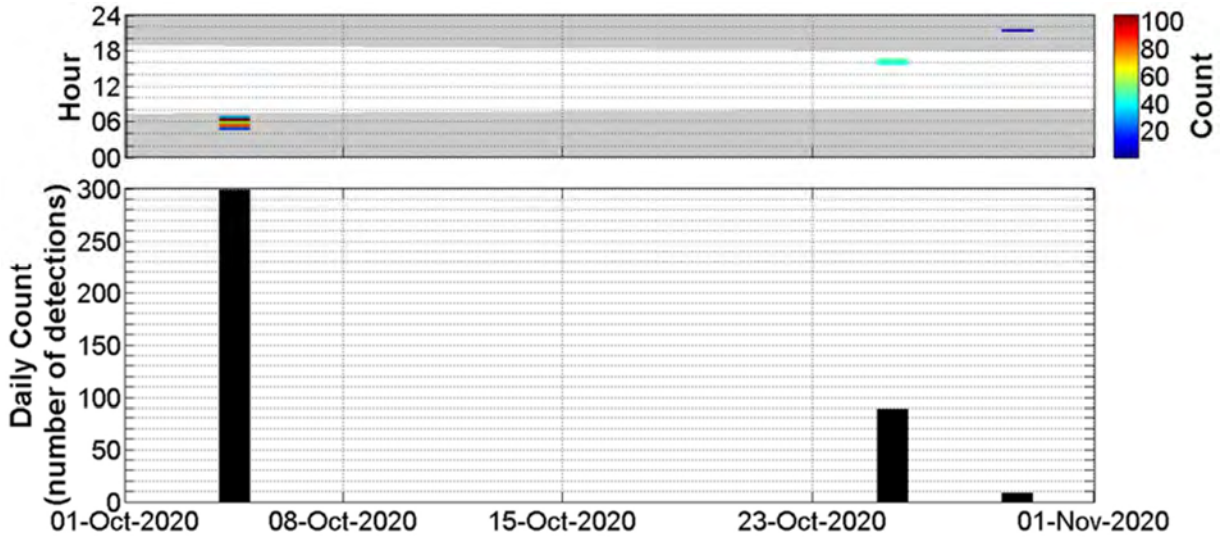

Figure B-27. Killer whale vocalizations at Monarch Head station for October 2020: Hourly and daily detection counts (PDT, UTC-7h). Grey areas indicate darkness period.

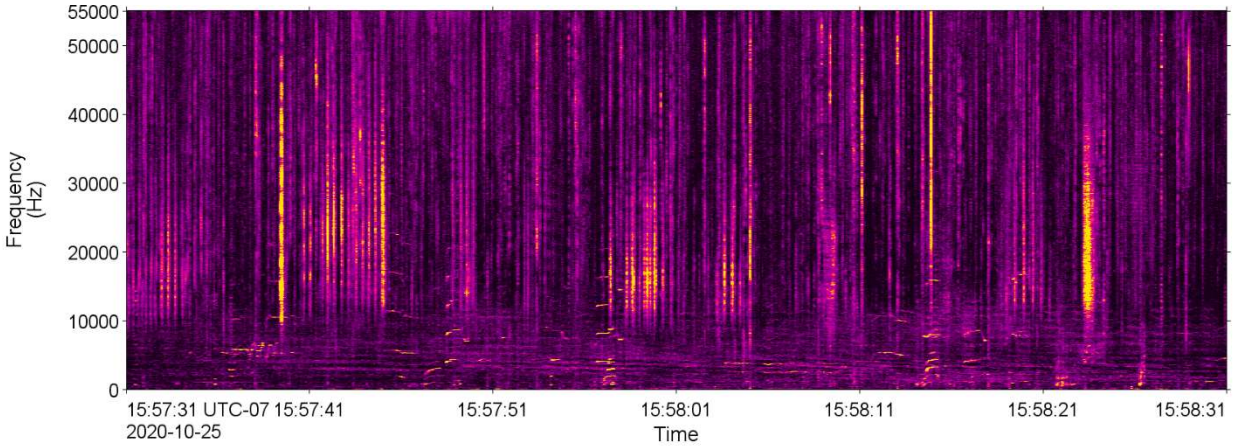

Figure B-28. Killer whales: Spectrogram of vocalizations at Monarch Head station on 25 Oct 2020 (PDT, UTC-7h).

B.10. November 2020

B.10.1. Relative Vocalization Detections by Species

A total of 928 humpback whale vocalizations were reported by the automated detector from 1–30 Nov 2020 at Monarch Head station. No killer whales and Pacific white-sided dolphins were detected at Monarch Head during this period. Figure B-29 shows the proportion of detections by species for this period.

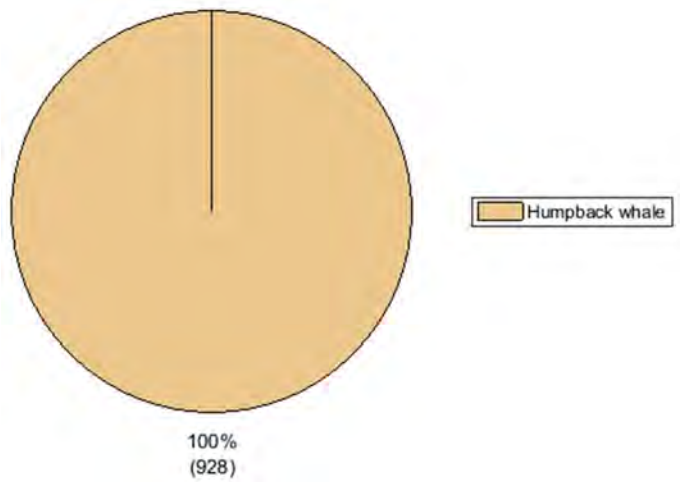

Figure B-29. Relative vocalization detections for 1–30 Nov 2020 at Monarch Head.

B.10.2. Humpback Whales

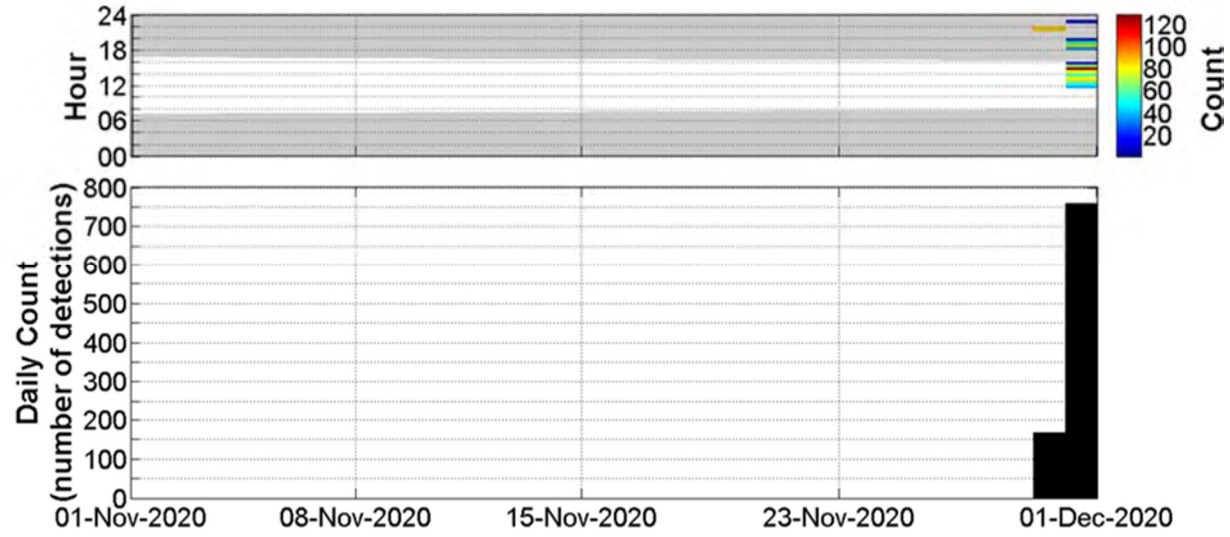

Figure B-30. Humpback whale vocalizations at Monarch Head station for November 2020: Hourly and daily detection counts (PST, UTC-8h). Grey areas indicate darkness period.

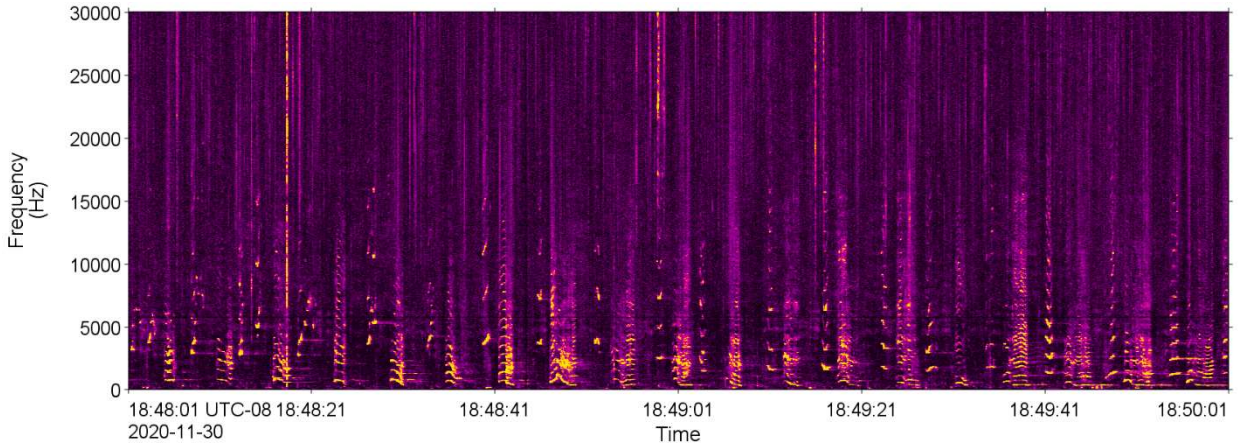

Figure B-31. Humpback whales: Spectrogram of vocalizations at Monarch Head station on 30 Nov 2020 (PST, UTC-8h).

B.11. December 2020

B.11.1. Relative Vocalization Detections By Species

A total of 1068 killer whale vocalizations and 1052 humpback whale vocalizations were reported by the automated detector from 1–31 Dec 2020 at Monarch Head station. No Pacific white-sided dolphins were detected at Monarch Head during this period. Figure B-32 shows the proportion of detections by species for this period.

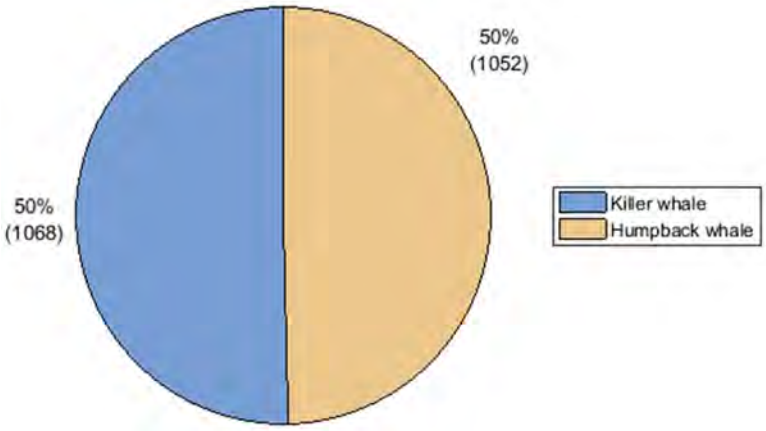

Figure B-32. Relative vocalization detections for 1–31 Dec 2020 at Monarch Head.

B.11.2. Killer Whales

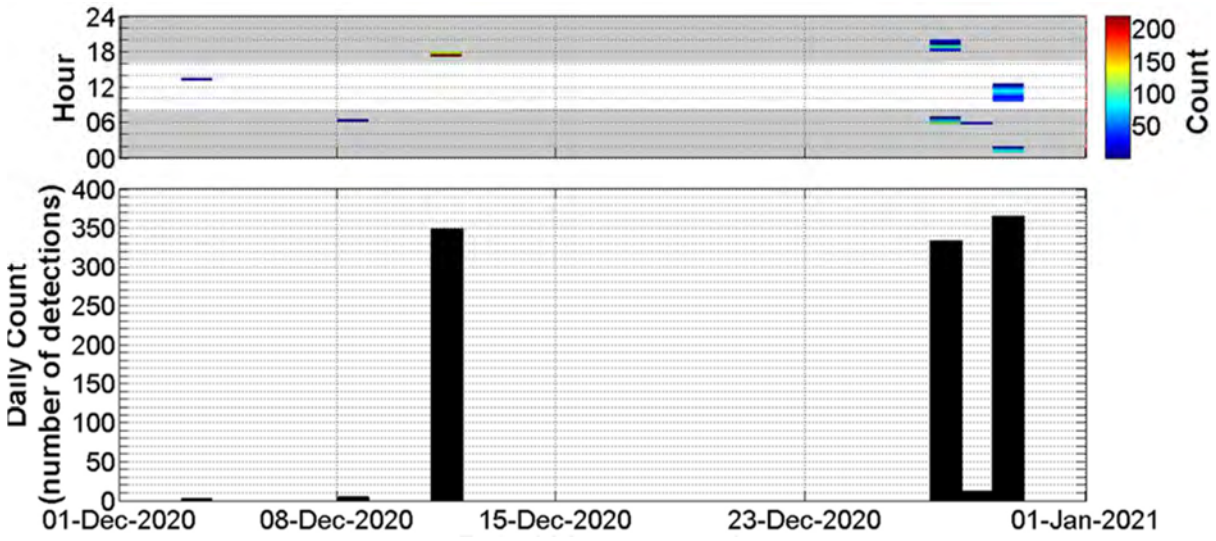

Figure B-33. Killer whale vocalizations at Monarch Head station for December 2020: Hourly and daily detection counts (PST, UTC-8h). Grey areas indicate darkness period.

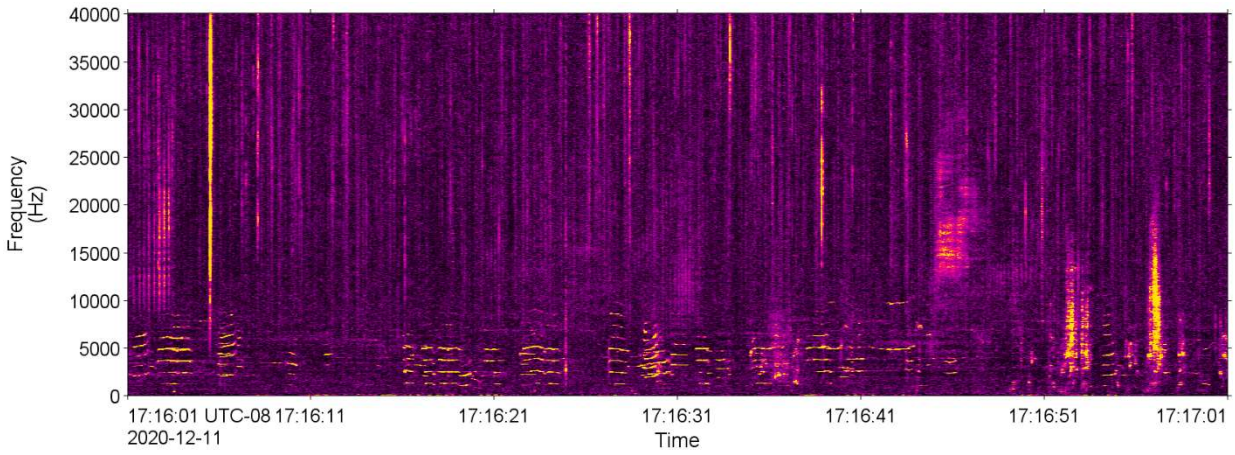

Figure B-34. Killer whales: Spectrogram of vocalizations at Monarch Head station on 11 Dec 2020 (PST, UTC-8h).

B.11.3. Humpback Whales

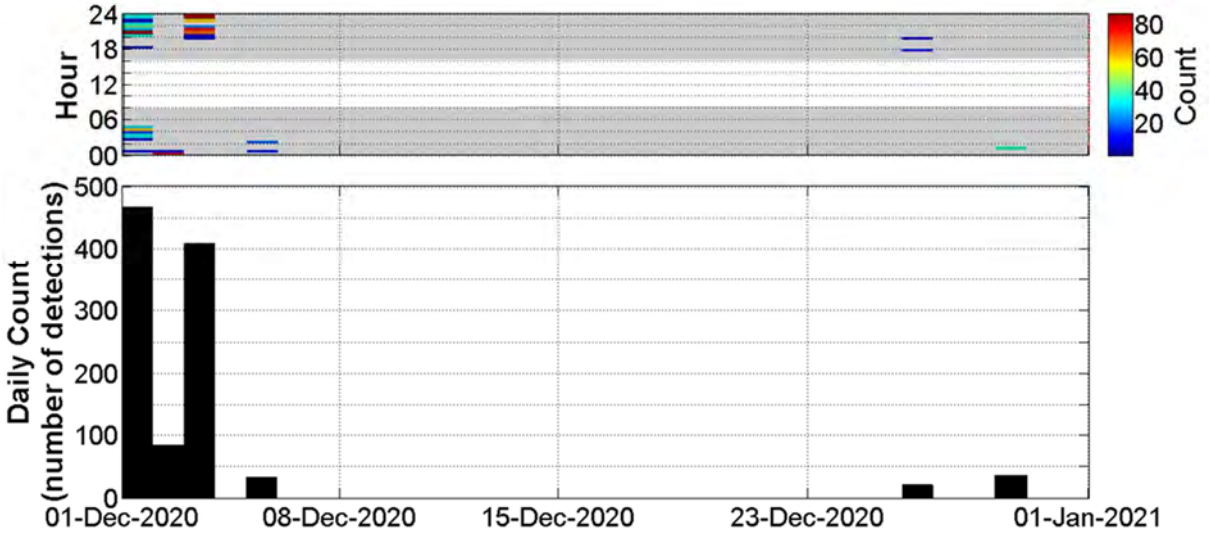

Figure B-35. Humpback whale vocalizations at Monarch Head station for December 2020: Hourly and daily detection counts (PST, UTC-8h). Grey areas indicate darkness period.

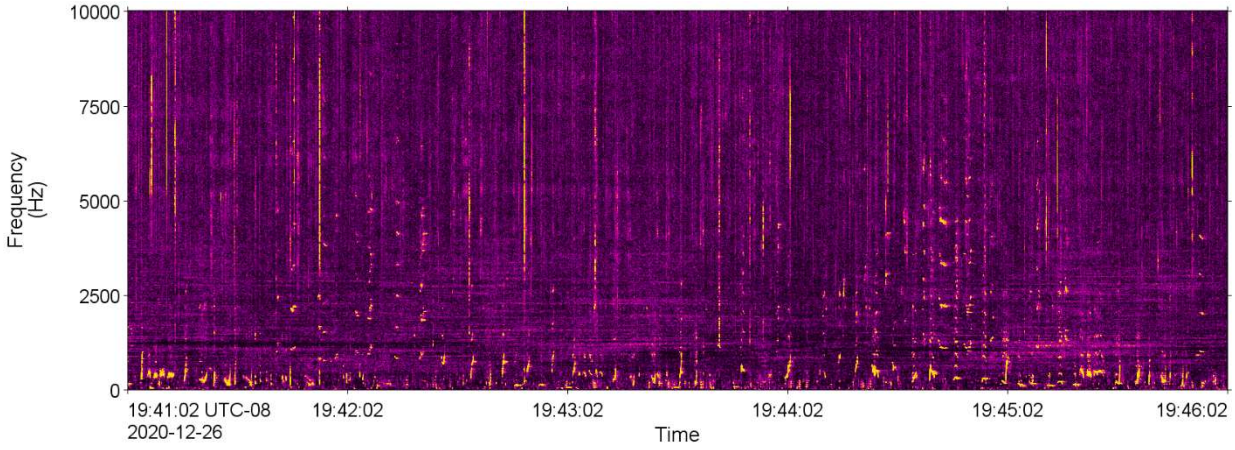

Figure B-36. Humpback whales: Spectrogram of vocalizations (song) at Monarch Head station on 26 Dec 2020 (PST, UTC-8h).

APPENDIX C. EAST POINT MONTHLY RESULTS

Results of marine mammal detections made on SIMRES's East Point hydrophone are provided here, segregated by month..

C.1. February 2020

C.1.1. Relative Vocalization Detections by Species

A total of 243 killer whale vocalizations were reported by the automated detector from 21–29 Feb 2020 at East Point station. No Pacific white-sided dolphins or humpback whales were detected at East Point during this period. Figure C-1 shows the proportion of detections by species for this period.

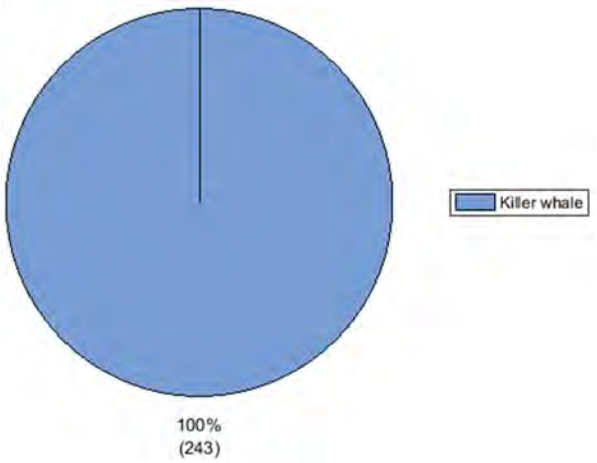

Figure C-1. Relative vocalization detections for 21–29 Feb 2020 at East Point.

C.1.2. Killer Whales

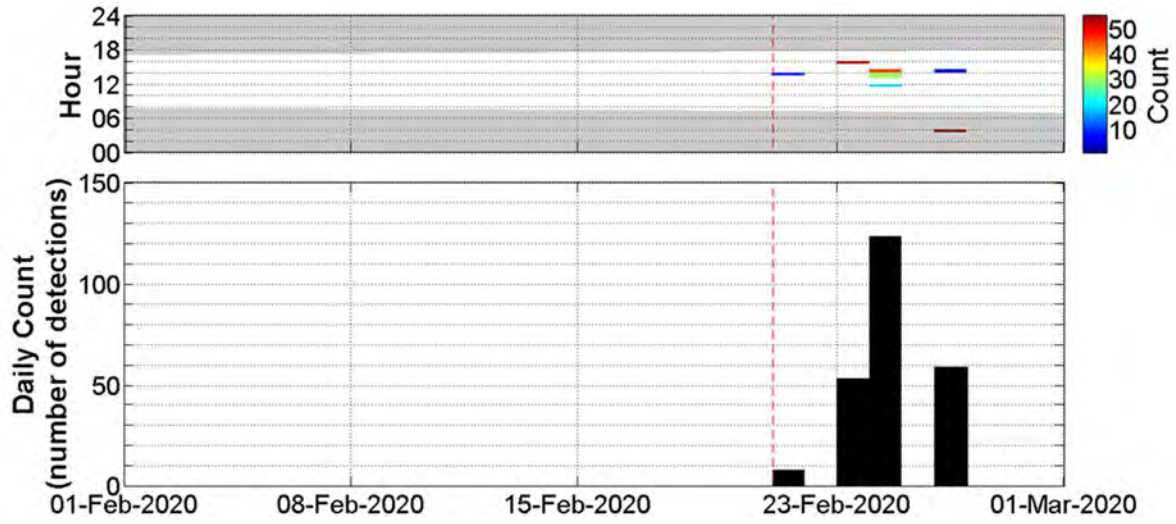

Figure C-2. Killer whale vocalizations at East Point station for February 2020: Hourly and daily detection counts (PST, UTC-8h). Grey areas indicate darkness period.

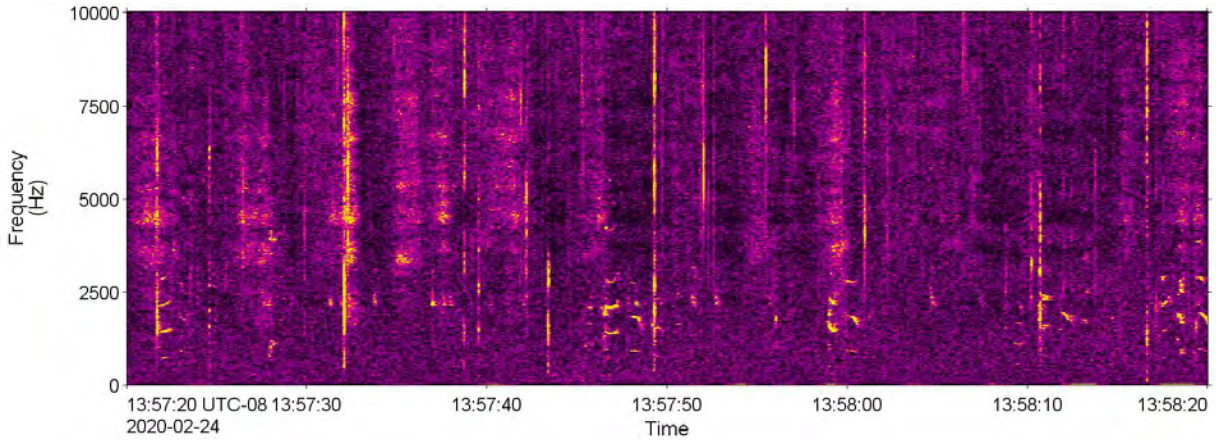

Figure C-3. Killer whales: Spectrogram of vocalizations at East Point station on 24 Feb 2020 (PST, UTC-8h).

C.2. March 2020

C.2.1. Relative Vocalization Detections by Species

A total of 2082 killer whale vocalizations were reported by the automated detector from 1–31 Mar 2020 at East Point station. No Pacific white-sided dolphins or humpback whales were detected at East Point during this period. Figure C-4 shows the proportion of detections by species for this period.

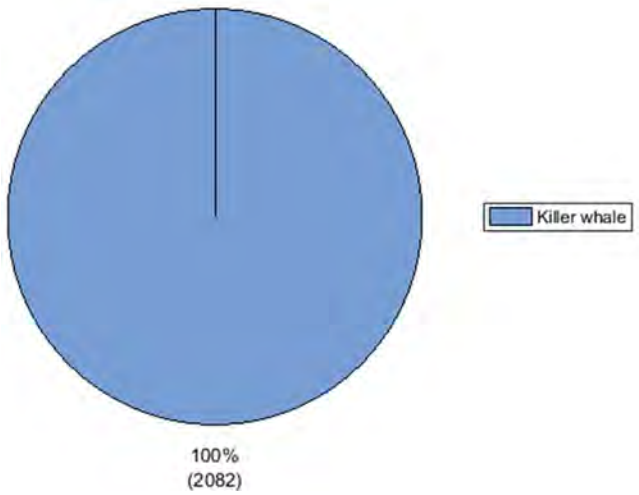

Figure C-4. Relative vocalization detections for 1–31 Mar 2020 at East Point.

C.2.2. Killer Whales

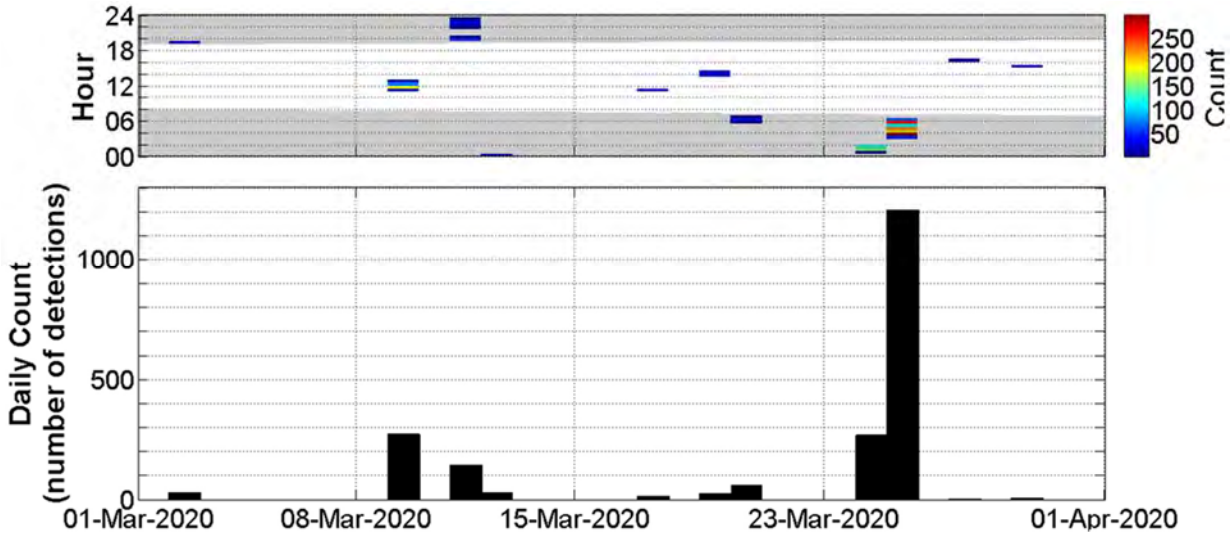

Figure C-5. Killer whale vocalizations at East Point station for March 2020: Hourly and daily detection counts (PDT, UTC-7h). Grey areas indicate darkness period.

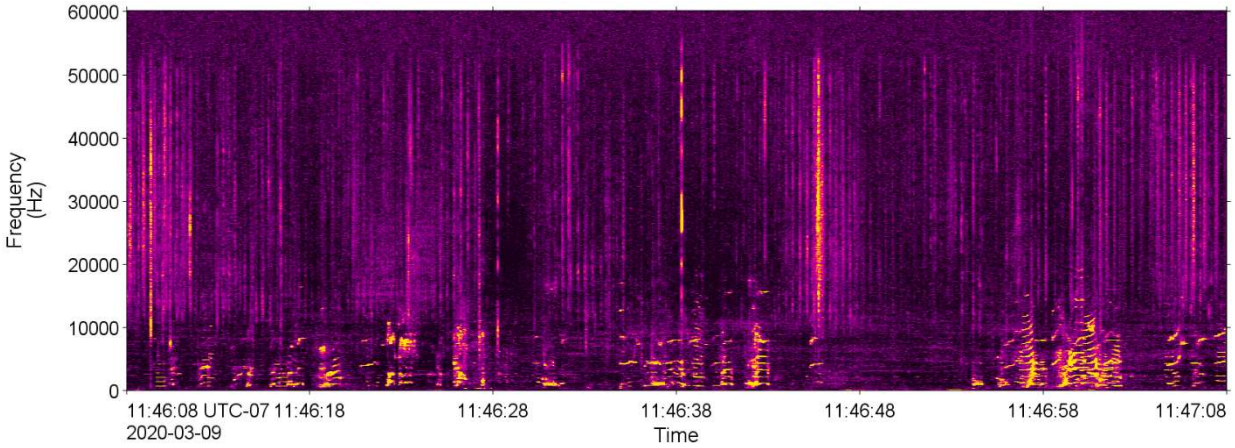

Figure C-6. Killer whales: Spectrogram of vocalizations at East Point station on 9 Mar 2020 (PDT, UTC-7h).

C.3. April 2020

C.3.1. Relative Vocalization Detections by Species

A total of 703 killer whale vocalizations were reported by the automated detector from 1–30 Apr 2020 at East Point station. No Pacific white-sided dolphins or humpback whales were detected at East Point during this period. Figure C-7 shows the proportion of detections by species for this period.

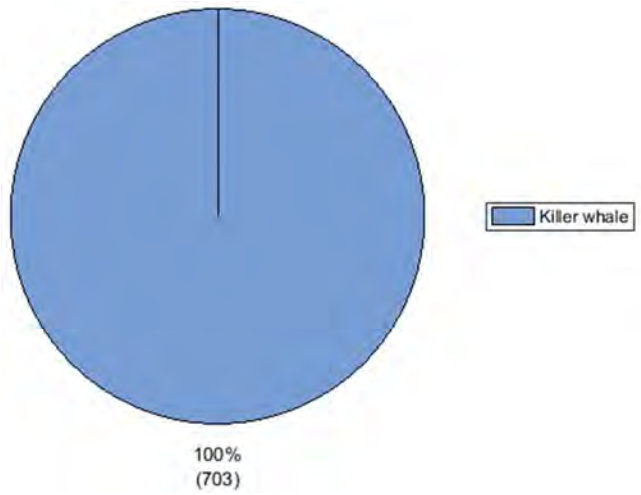

Figure C-7. Relative vocalization detections for 1–30 Apr 2020 at East Point.

C.3.2. Killer Whales

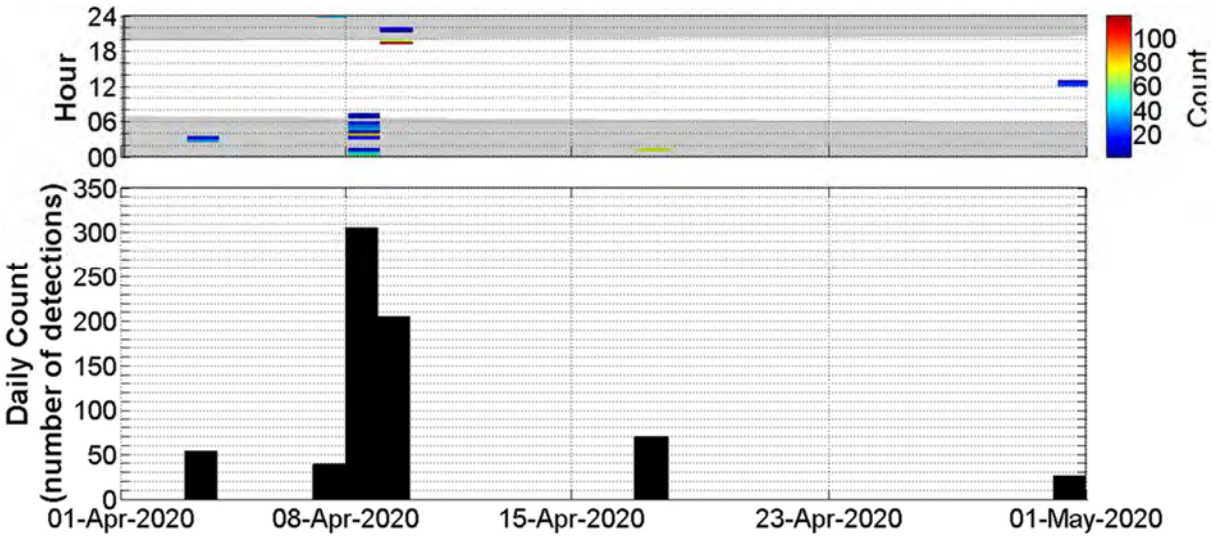

Figure C-8. Killer whale vocalizations at East Point station for April 2020: Hourly and daily detection counts (PDT, UTC-7h). Grey areas indicate darkness period.

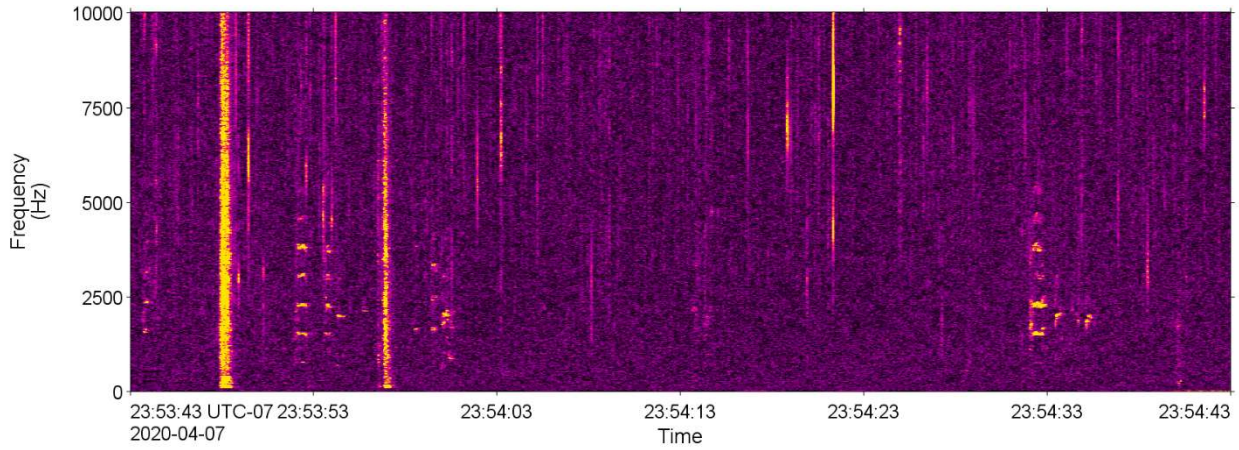

Figure C-9. Killer whales: Spectrogram of vocalizations at East Point station on 7 Apr 2020 (PDT, UTC-7h).

C.4. May 2020

Acoustic data from East Point from 1–11 May 2020 were not available for analysis.

C.4.1. Relative Vocalization Detections by Species

A total of 34 killer whale vocalizations were reported by the automated detector from 12–31 May 2020 at East Point station. No Pacific white-sided dolphins or humpback whales were detected at East Point during this period. Figure C-10 shows the proportion of detections by species for this period.

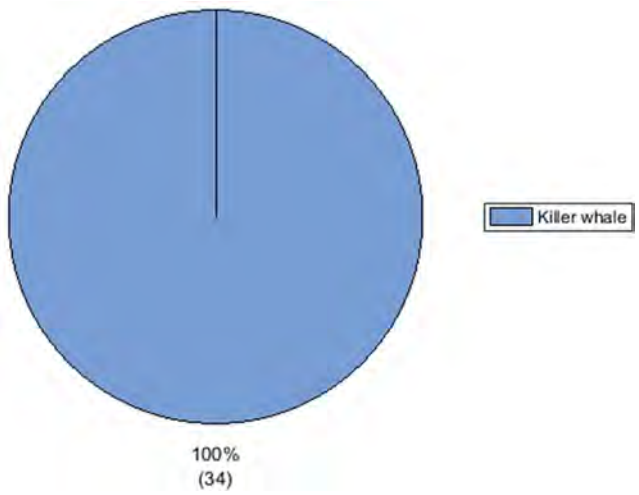

Figure C-10. Relative vocalization detections for 12–31 May 2020 at East Point.

C.4.2. Killer Whales

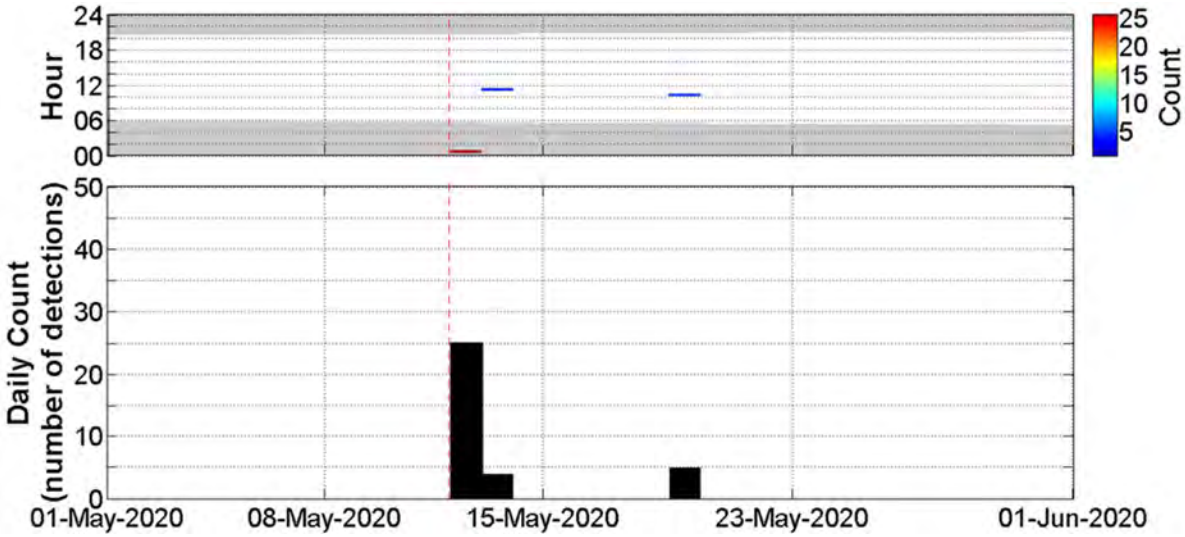

Figure C-11. Killer whale vocalizations at East Point station for May 2020: Hourly and daily detection counts (PDT, UTC-7h). Grey areas indicate darkness period.

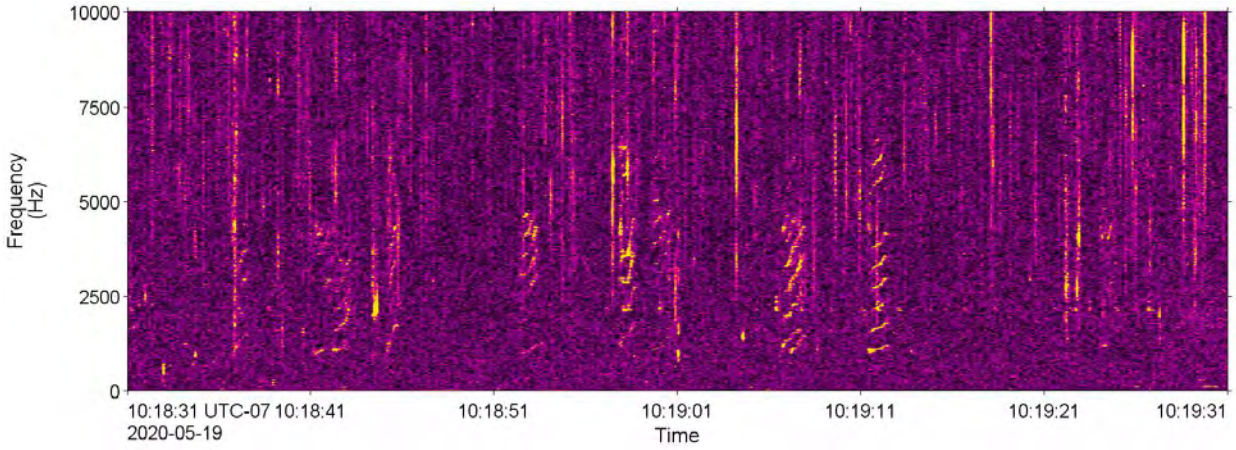

Figure C-12. Killer whales: Spectrogram of vocalizations at East Point station on 19 May 2020 (PDT, UTC-7h).

C.5. June 2020

C.5.1. Relative Vocalization Detections by Species

A total of 87 killer whale vocalizations were reported by the automated detector from 1–30 Jun 2020 at East Point station. No Pacific white-sided dolphins or humpback whales were detected at East Point during this period. Figure C-13 shows the proportion of detections by species for this period.

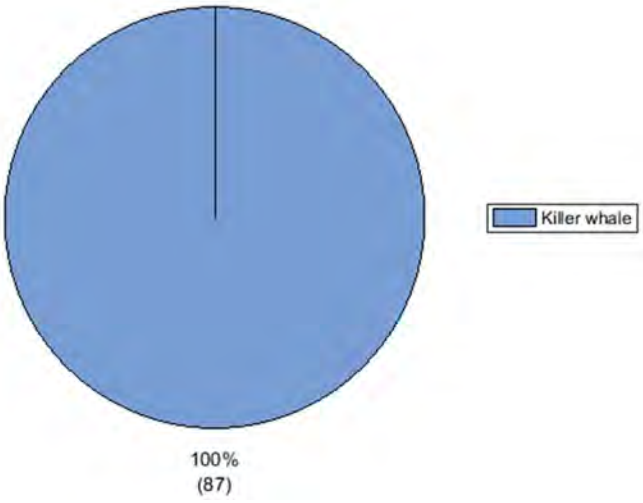

Figure C-13. Relative vocalization detections for 1–30 Jun 2020 at East Point.

C.5.2. Killer Whales

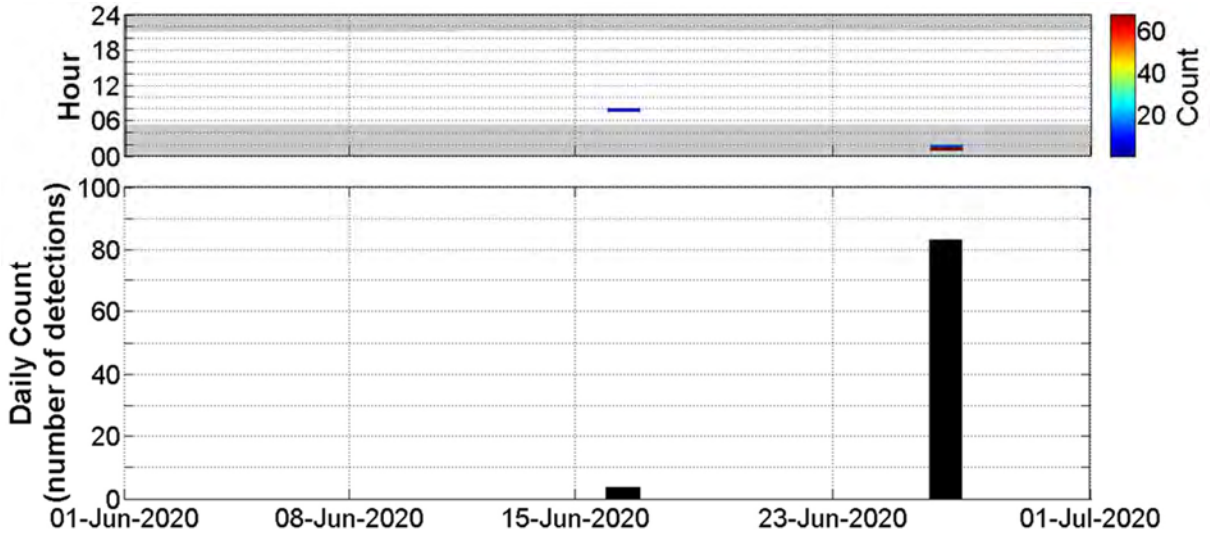

Figure C-14. Killer whale vocalizations at East Point station for June 2020: Hourly and daily detection counts (PDT, UTC-7h). Grey areas indicate darkness period.

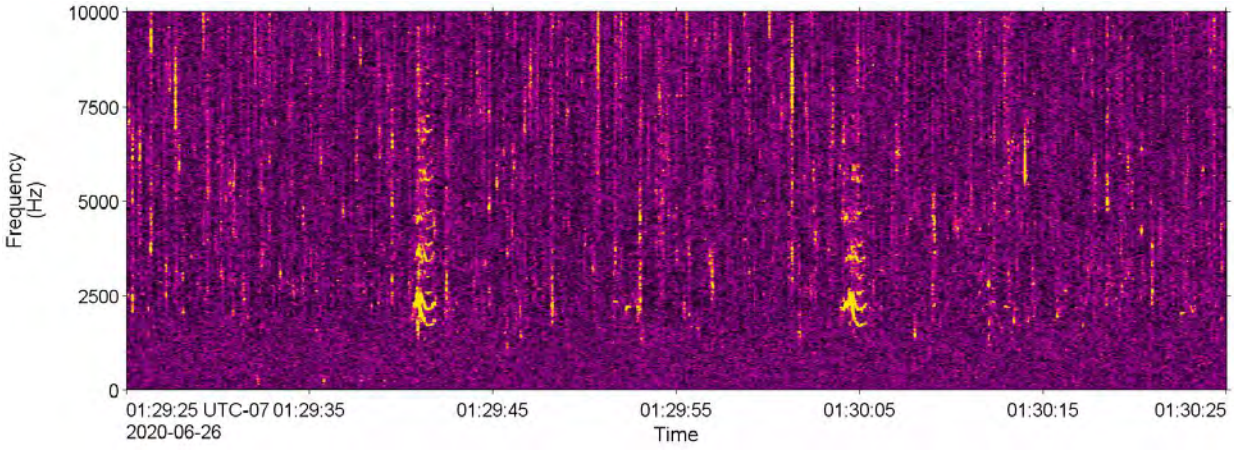

Figure C-15. Killer whales: Spectrogram of vocalizations at East Point station on 26 Jun 2020 (PDT, UTC-7h).

C.6. July 2020

Acoustic data from East Point from 7–16 Jul 2020 were not available for analysis.

C.6.1. Relative Vocalization Detections by Species

A total of 139 killer whale vocalizations were reported by the automated detector from 1–6 and 17–31 Jul 2020 at East Point station. No Pacific white-sided dolphins or humpback whales were detected at East Point during this period. Figure C-16 shows the proportion of detections by species for this period.

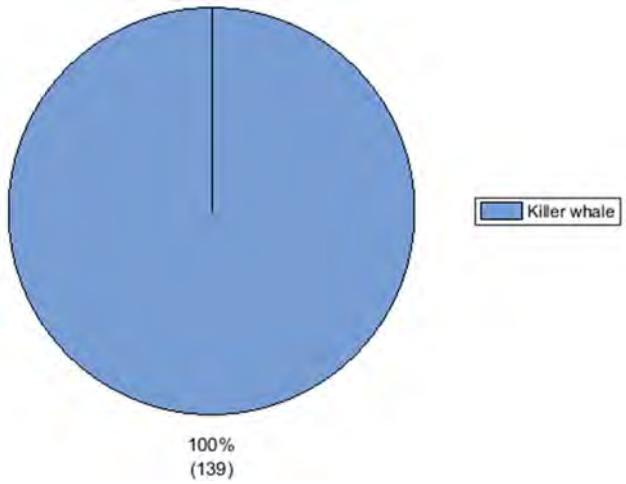

Figure C-16. Relative vocalization detections for 1–6 and 17–31 Jul 2020 at East Point.

C.6.2. Killer Whales

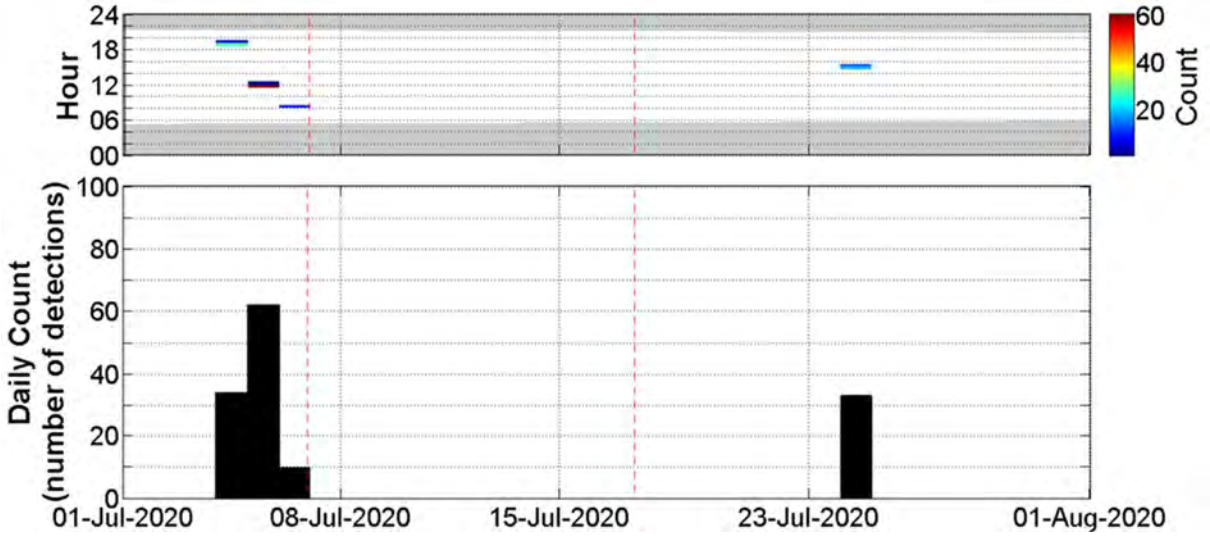

Figure C-17. Killer whale vocalizations at East Point station for July 2020: Hourly and daily detection counts (PDT, UTC-7h). Grey areas indicate darkness period.

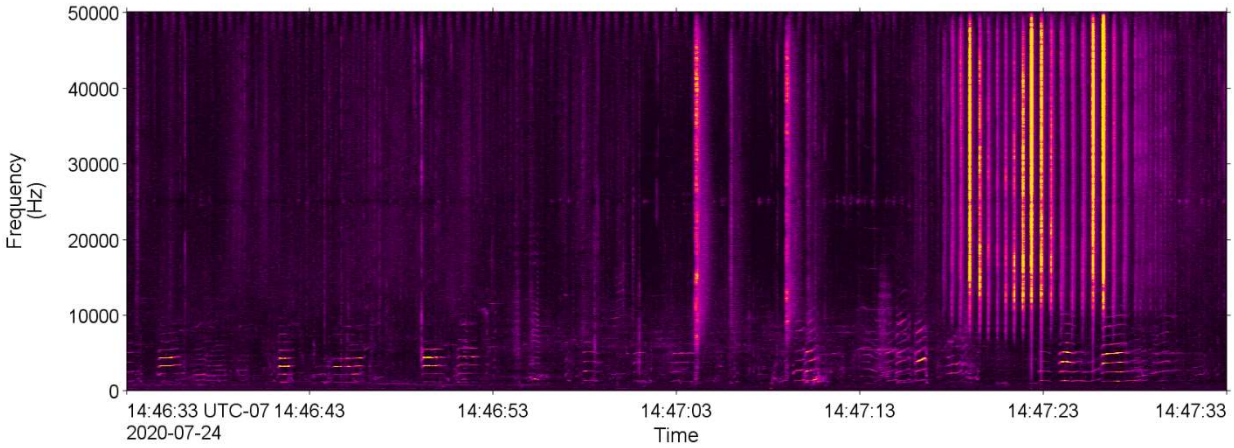

Figure C-18. Killer whales: Spectrogram of vocalizations at East Point station on 24 Jul 2020 (PDT, UTC-7h).

C.7. August 2020

C.7.1. Relative Vocalization Detections by Species

A total of 4 killer whale vocalizations were reported by the automated detector from 1–31 Aug 2020 at East Point station. No Pacific white-sided dolphins or humpback whales were detected at East Point during this period. Figure C-19 shows the proportion of detections by species for this period.

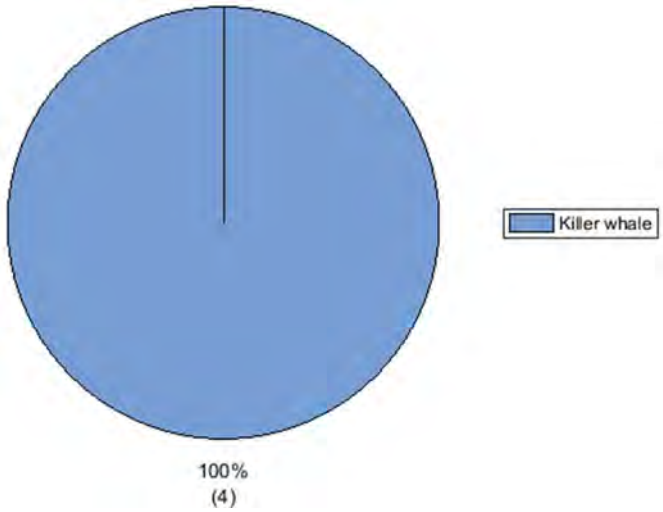

Figure C-19. Relative vocalization detections for 1–31 Aug 2020 at East Point.

C.7.2. Killer Whales

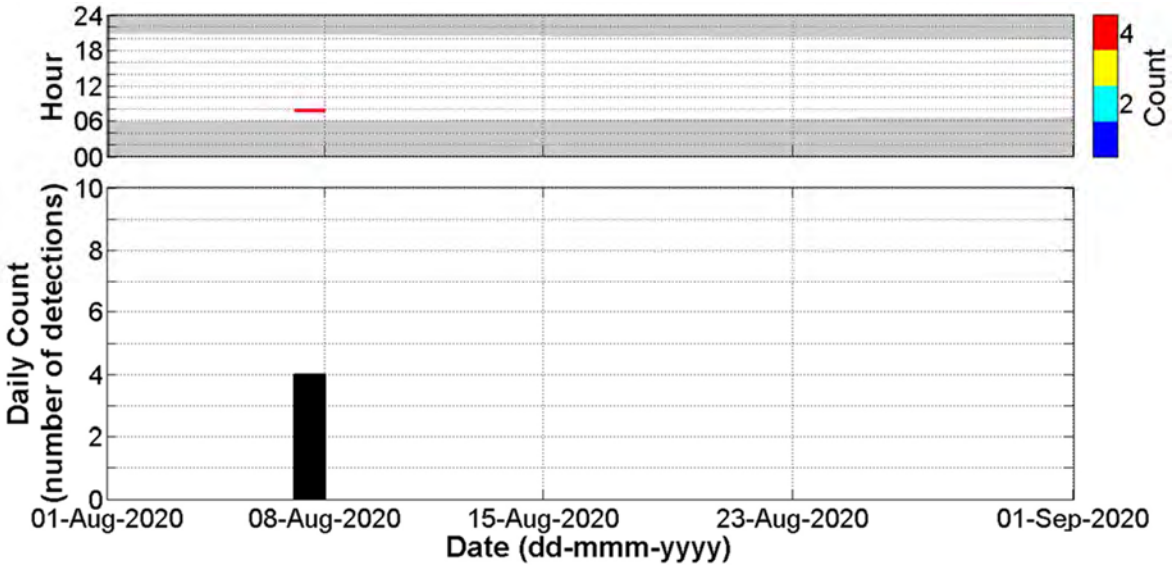

Figure C-20. Killer whale vocalizations at East Point station for August 2020: Hourly and daily detection counts (PDT, UTC-7h). Grey areas indicate darkness period.

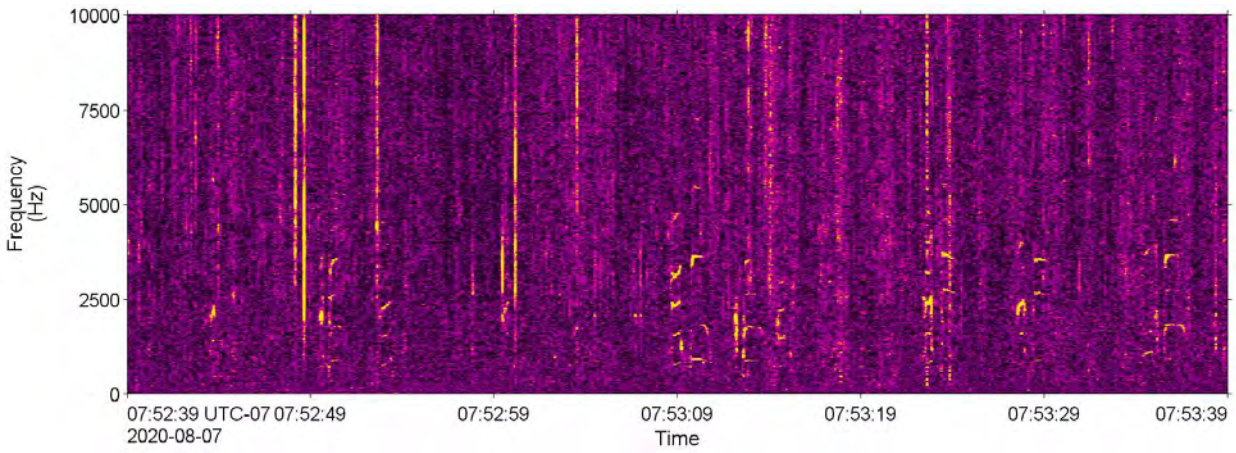

Figure C-21. Killer whales: Spectrogram of vocalizations at East Point station on 7 Aug 2020 (PDT, UTC-7h).

C.8. September 2020

C.8.1. Relative Vocalization Detections by Species

A total of 401 killer whale vocalizations were reported by the automated detector from 1–30 Sep 2020 at East Point station. No Pacific white-sided dolphins or humpback whales were detected at East Point during this period. Figure C-22 shows the proportion of detections by species for this period.

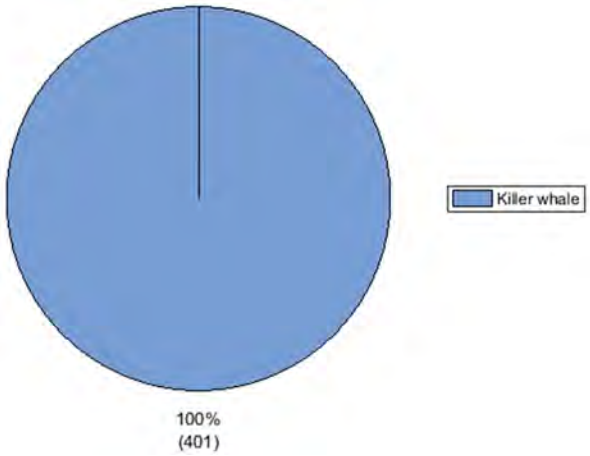

Figure C-22. Relative vocalization detections for 1–30 Sep 2020 at East Point.

C.8.2. Killer Whales

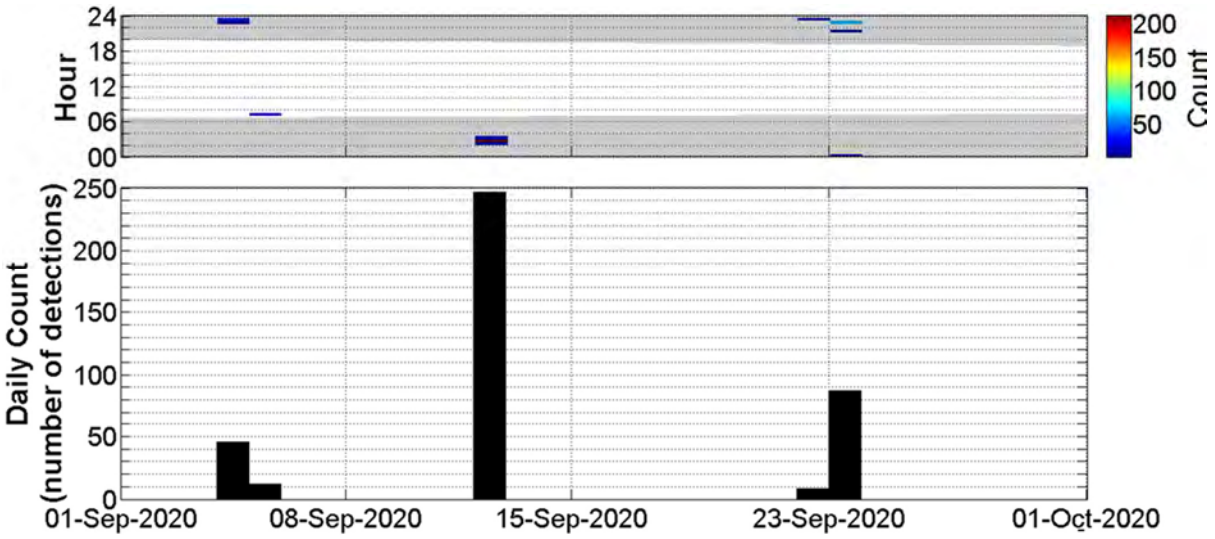

Figure C-23. Killer whale vocalizations at East Point station for September 2020: Hourly and daily detection counts (PDT, UTC-7h). Grey areas indicate darkness period.

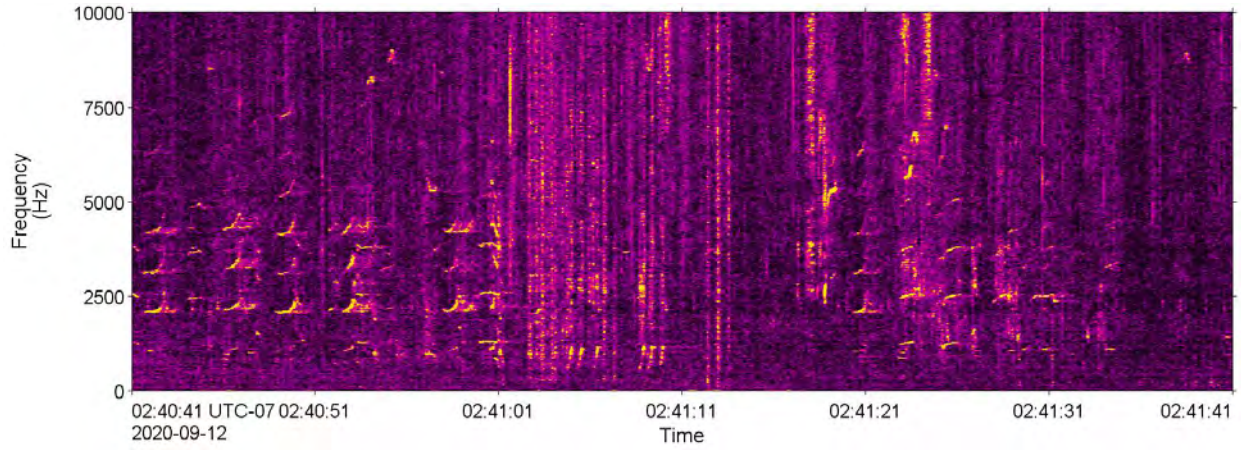

Figure C-24. Killer whales: Spectrogram of vocalizations at East Point station on 12 Sep 2020 (PDT, UTC-7h).

C.9. October 2020

C.9.1. Relative Vocalization Detections by Species

A total of 18 killer whale vocalizations were reported by the automated detector from 3–31 Oct 2020 at East Point station. No Pacific white-sided dolphins or humpback whales were detected at East Point during this period. Figure C-25 shows the proportion of detections by species for this period.

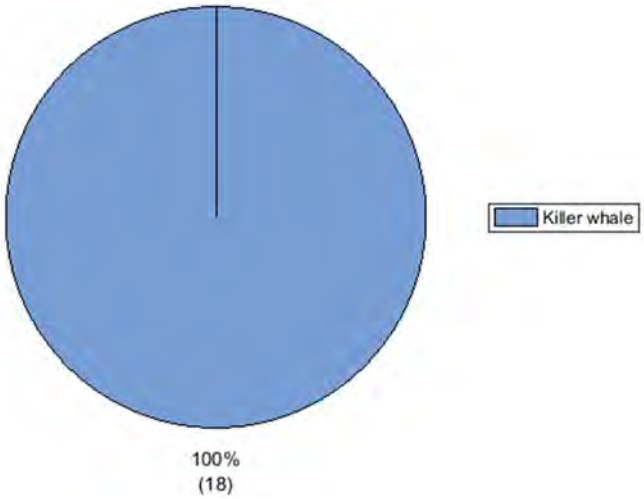

Figure C-25. Relative vocalization detections for 3–31 Oct 2020 at East Point.

C.9.2. Killer Whales

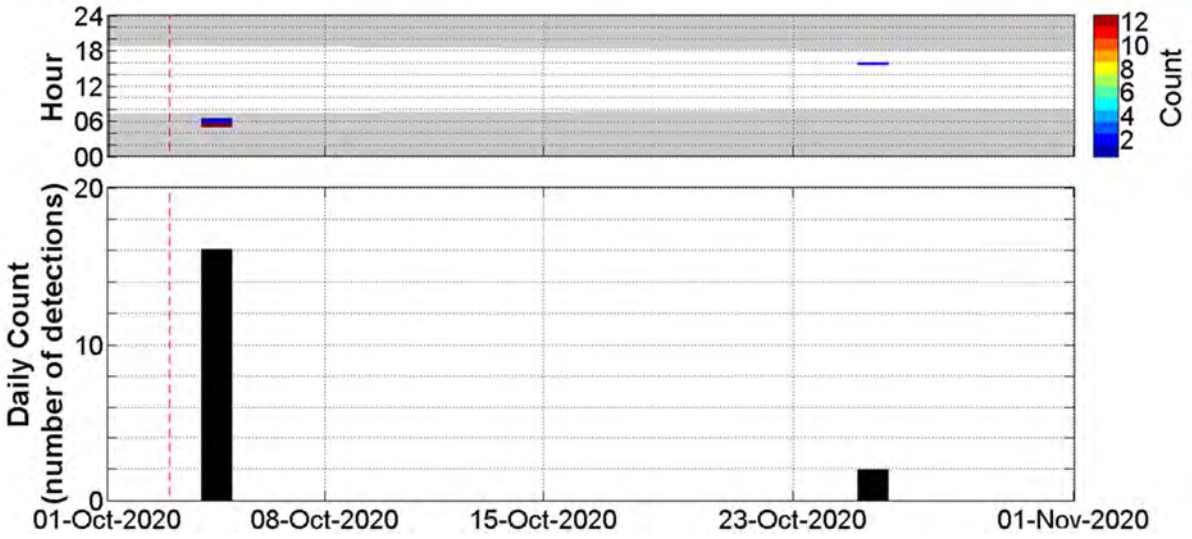

Figure C-26. Killer whale vocalizations at East Point station for October 2020: Hourly and daily detection counts (PDT, UTC-7h). Grey areas indicate darkness period.

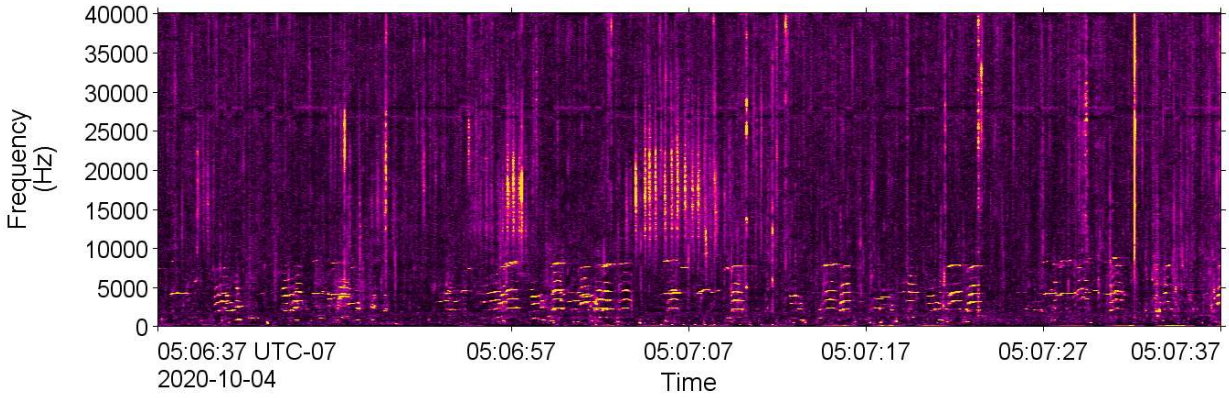

Figure C-27. Killer whales: Spectrogram of vocalizations at East Point station on 4 Oct 2020 (PDT, UTC-7h).

C.10. November 2020

C.10.1. Relative Vocalization Detections by Species

A total of 45 humpback whale vocalizations were reported by the automated detector from 1–30 Nov 2020 at East Point station. No killer whales and Pacific white-sided dolphins were detected at East Point during this period. Figure C-28 shows the proportion of detections by species for this period.

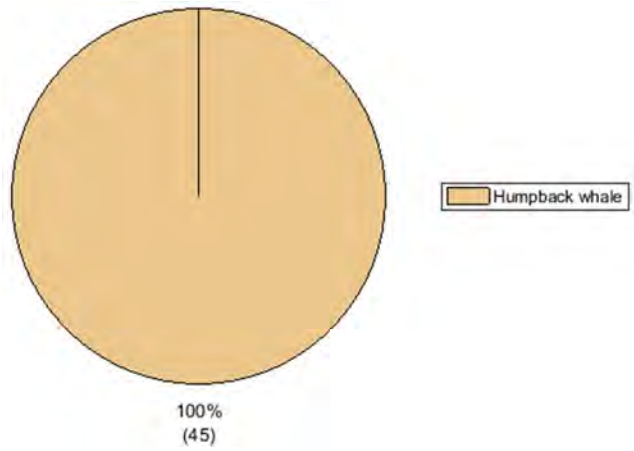

Figure C-28. Relative vocalization detections for 1–30 Nov 2020 at East Point.

C.10.2. Humpback Whales

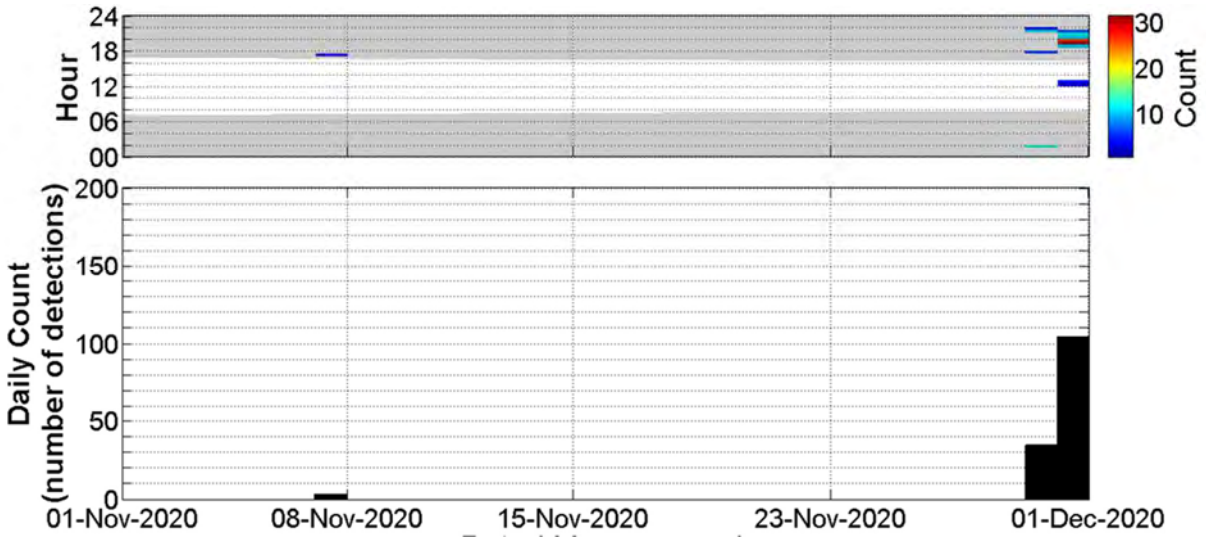

Figure C-29. Humpback whale vocalizations at East Point station for November 2020: Hourly and daily detection counts (PST, UTC-8h). Grey areas indicate darkness period.

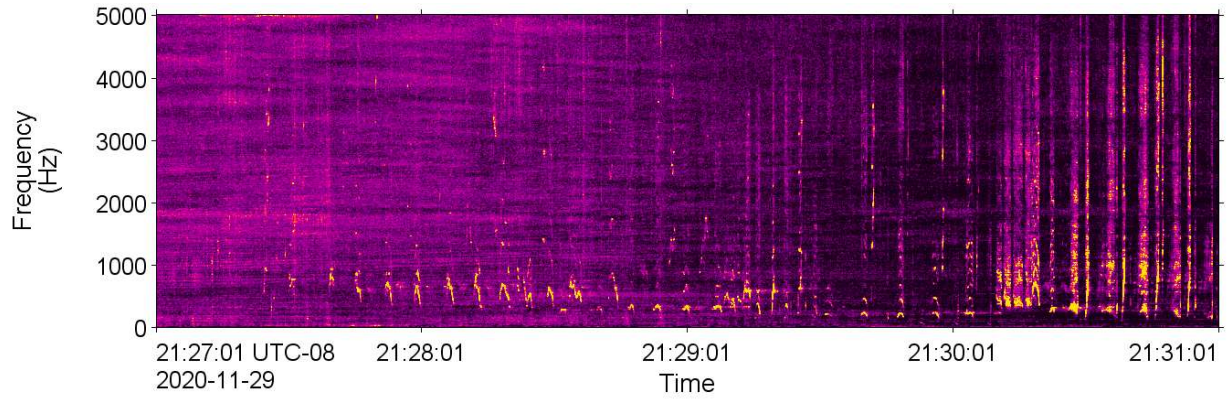

Figure C-30. Humpback whales: Spectrogram of vocalizations at East Point station on 29 Nov 2020 (PST, UTC-8h).

C.11. December 2020

C.11.1. Relative Vocalization Detections by Species

A total of 94 killer whale vocalizations and 1299 humpback whale vocalizations were reported by the automated detector from 1–31 Dec 2020 at East Point station. No Pacific white-sided dolphins were detected at East Point during this period. Figure C-31 shows the proportion of detections by species for this period.

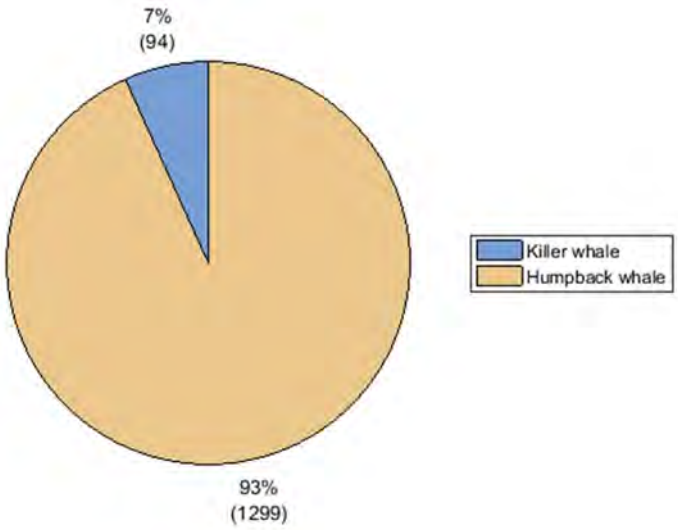

Figure C-31. Relative vocalization detections for 1–31 Dec 2020 at East Point.

C.11.2. Killer Whales

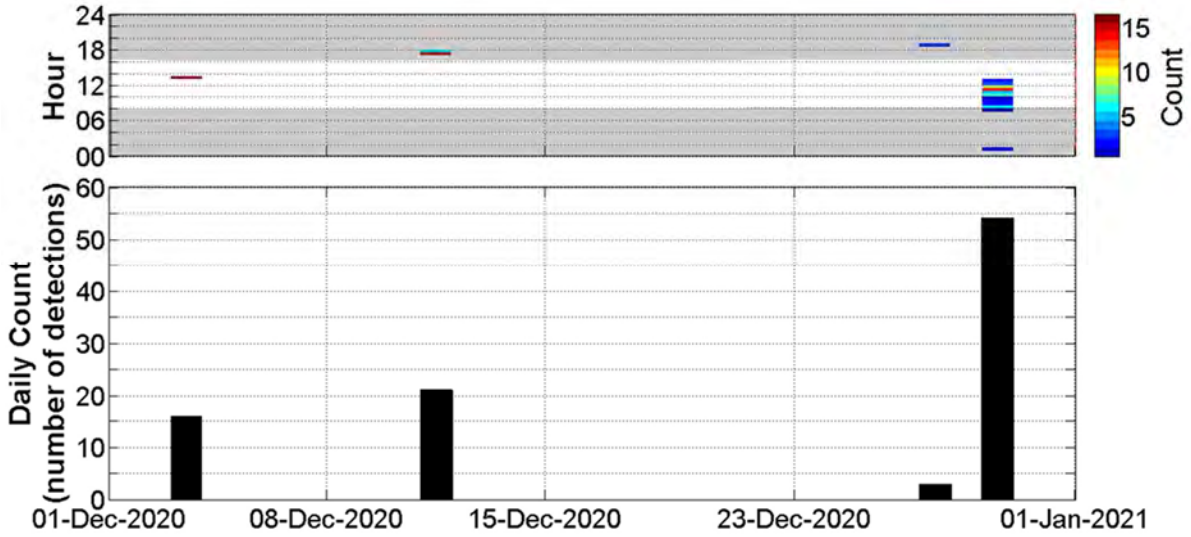

Figure C-32. Killer whale vocalizations at East Point station for December 2020: Hourly and daily detection counts (PST, UTC-8h). Grey areas indicate darkness period.

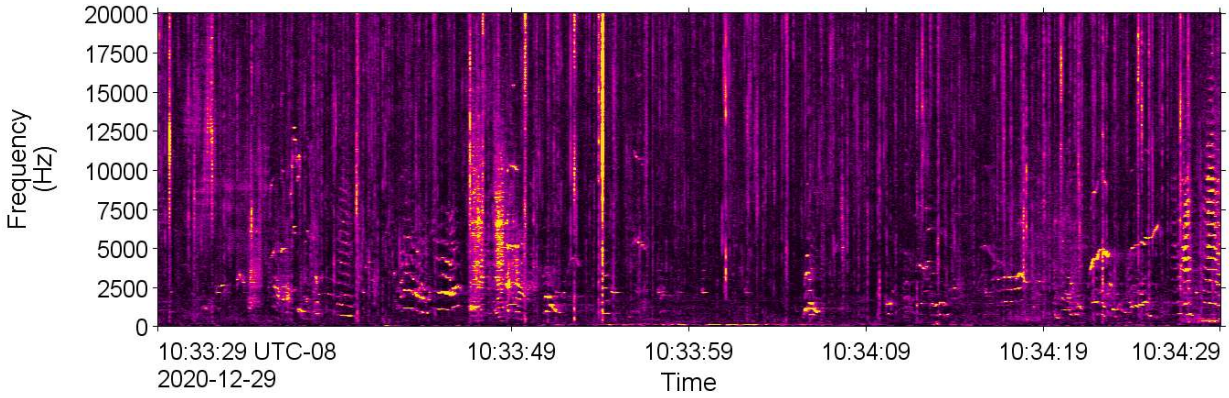

Figure C-33. Killer whales: Spectrogram of vocalizations at East Point station on 29 Dec 2020 (PST, UTC-8h).

C.11.3. Humpback Whales

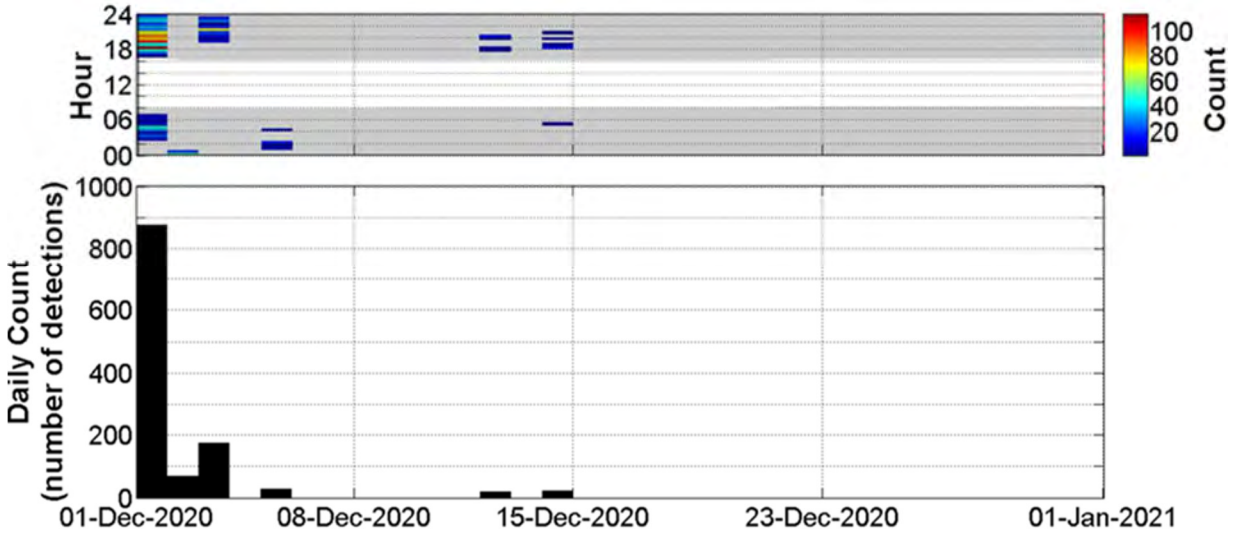

Figure C-34. Humpback whale vocalizations at East Point station for December 2020: Hourly and daily detection counts (PST, UTC-8h). Grey areas indicate darkness period.

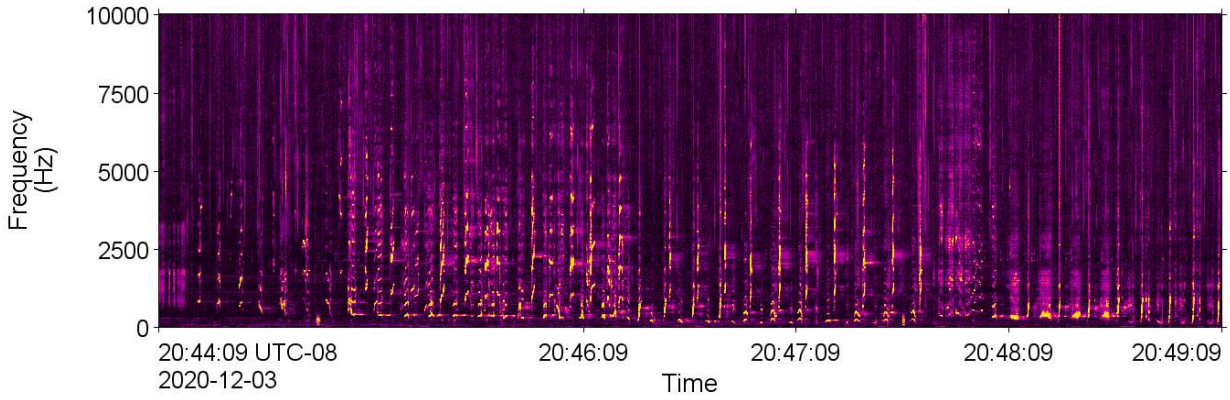

Figure C-35. Humpback whales: Spectrogram of vocalizations at East Point station on 3 Dec 2020 (PST, UTC-8h).